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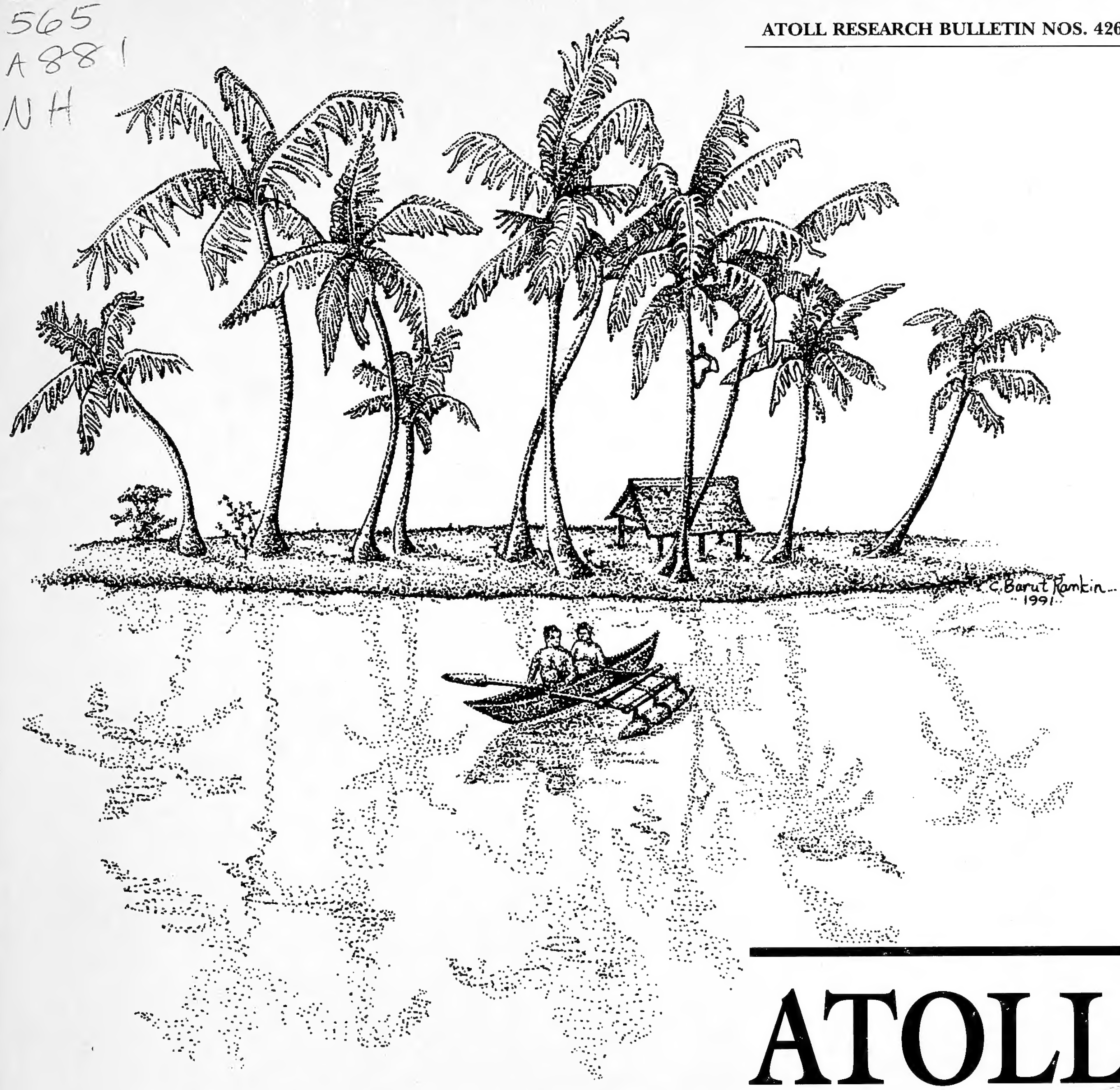

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BIOLOGY AND GEOLOGY OF TOBACCO RANGE BELIZE, CENTRAL AMERICA: *A Mangrove System Containing Unique Fractured Peat Deposits*

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BIOLOGY AND GEOLOGY OF TOBACCO RANGE, BELIZE, CENTRAL AMERICA: A MANGROVE SYSTEM CONTAINING UNIQUE FRACTURED PEAT DEPOSITS

EDITED BY

MARK M. LITTLER, IAN G. MACINTYRE, AND DIANE S. LITTLER

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Aerial view eastward toward the Tobacco Range fracture zone and the adjacent northeast mangrove island. The small white object in the central fracture depression (center of photograph) is the 5-m long inflatable research boat used in the study.

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INTRODUCTION TO THE BIOLOGY AND GEOLOGY OF TOBACCO RANGE, BELIZE, C.A.

BY

M.M. LITTLER, D.S. LITTLER, AND I.G. MACINTYRE

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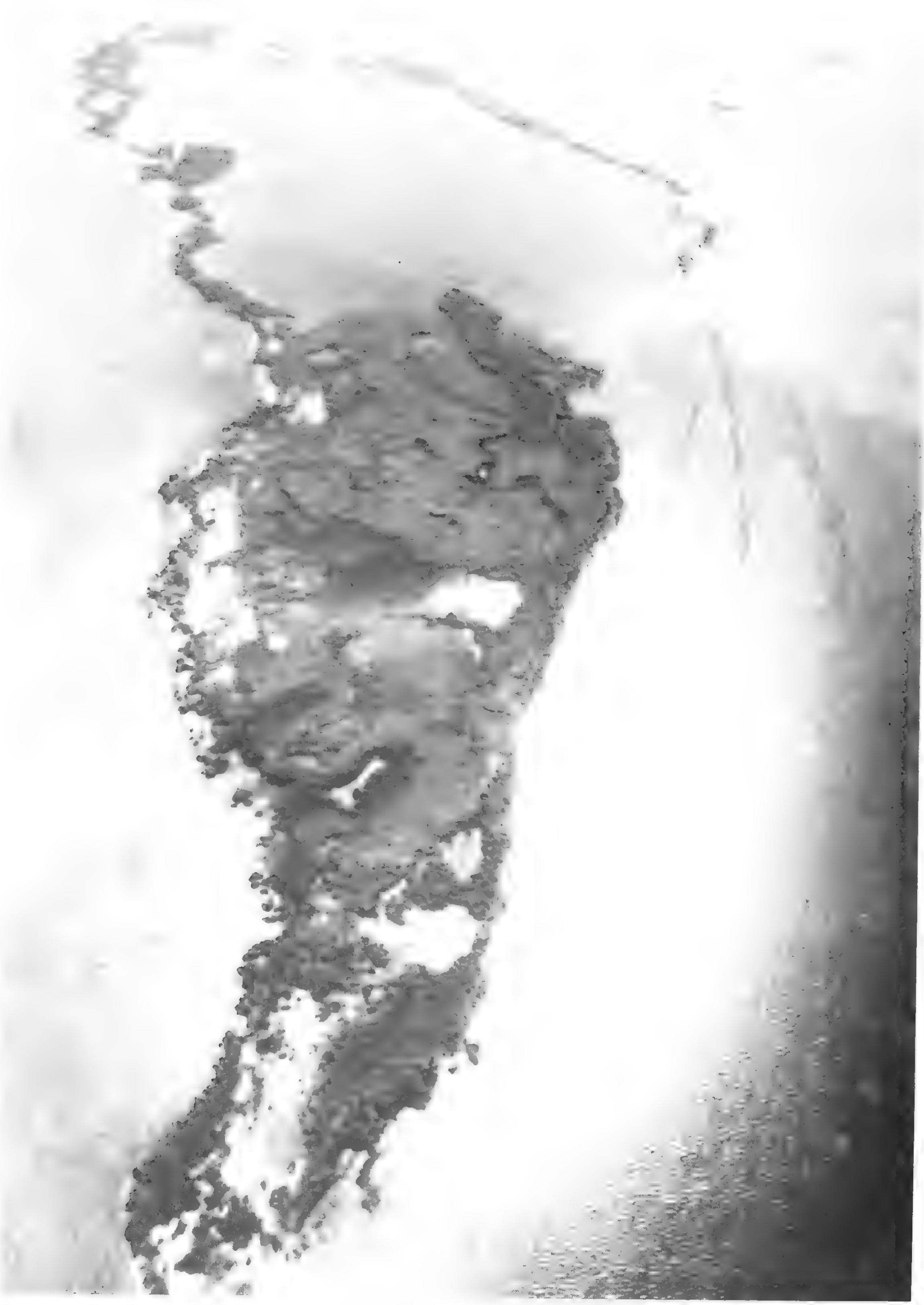

Figure 1. Oblique wide-angle aerial photograph of Tobacco Range, looking from the northeast toward the southwest.

INTRODUCTION TO THE BIOLOGY AND GEOLOGY OF TOBACCO RANGE, BELIZE, C.A.

BY

Mark M. Littler[1], Diane S. Littler[1], and Ian G. Macintyre[2]

The Belize Barrier Reef complex varies from 10 to 32 km in width and is over 200 km in length. The complex is composed of diverse intertidal and subtidal barrier and patch reef zones, three large atolls, vast lagoonal seagrass beds, and hundreds of mangrove islands. The Barrier Reef complex is established on the Yucatan Block, an almost continuous series of limestone deposits formed during the Cretaceous to Pliocene (Miller and Macintyre, 1977). During the Pliocene, the Yucatan Block was tilted northward to form the Campeche Bank, whereas a set of north-northwest trending faults produced submarine escarpments on the eastern margin, influencing the geomorphology of the Belize continental shelf.

The Belize Barrier Reef runs approximately parallel to the faults, and raised blocks formed during the Pleistocene on the continental shelf have provided critical shallow-water foundations for reef-forming organisms (Purdy, 1974). Extensive mangrove communities also developed on these elevated Pleistocene reliefs in low energy environments behind the active margin of the Barrier Reef (Chapman, 1976; Woodroffe, 1983) as the shelf became flooded by the rising seas of the Holocene transgression. Most of these mangrove communities ultimately were drowned and subsequently buried by calcareous marine sediments, except in the areas of higher Pleistocene relief where mangrove systems such as Tobacco Range have traced the rising sea level for the past 7,000 to 9,000 yrs (Macintyre et al., 1995, this volume).

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Tobacco Range is a roughly oval (atoll-like) group of mangrove islands (Fig. 1) surrounding a central 2 m-deep lagoon on the outer platform of the Belize Barrier Reef about 2 km west of the Barrier Reef crest. The Tobacco Range mangrove system is approximately 1.7 km wide and 4 km long with the largest island lying at the northeast of the complex. Two long narrow islands to the southeast and southwest complete the lagoonal margin (Fig. 1).

The climate of the Tobacco Range region of the Belize barrier reef is drier than the coastal mainland (Woodroffe, 1995, this volume). The Dangriga coastline to the west receives more than 2000 mm of rainfall per year, mostly during June to October. Nearby, Carrie Bow Cay receives an annual rainfall of about half that at Dangriga (Rützler and Ferraris, 1982). The prevailing winds are northeast tradewinds, although there are times during the dry season when low pressure systems with associated fronts bring northwest winds that are often accompanied by strong waves (Perkins, 1983). The area also is vulnerable to hurricanes during July to October, and was devastated by the passage of Hurricane Hattie in 1961 (Stoddart, 1963, 1974).

Our attention became focused on the atoll-like Tobacco Range mangrove group in February 1986 when a 0.5 km-wide by 2.0 km-long region of fractured and slumped fossil peat was discovered (Littler et al., 1995, this volume) off the west coast of the northeastern island. Sediment-core samples from seven vibracores and ten soil-sampling probes across the northeastern island indicated (Macintyre et al., 1995, this volume) that this ecosystem has been dominated by mangrove communities throughout its entire Holocene history. Samples from cores and probes documented some of the thickest mangrove peat sections ever recorded, up to 10 m thick, with thin basal mud sections overlying the eroded Pleistocene limestone surface. This peat consists of upper sections of spongy, well-preserved, coarse-fibered peat with conspicuous plant fragments, which overlie a partially decomposed dense fine-fibered peat with almost no recognizable macroscopic plant remains. The basal muds, which consist of a mixture of calcareous and non-carbonate sediments, are probably a reworked wetland soil. Peat-depositing mangrove communities became established on this Pleistocene limestone area of high topographic relief about 7,000 yrs B.P. and accumulated peat at a mean rate of 4.3 m per millennium, which was sufficient to keep pace with the rising sea levels during the Holocene transgression. Radiocarbon dates of Tobacco Range peat samples confirm (Macintyre et al., 1995, this volume) that the late Holocene history of sea-level rise in Belize is consistent with that reported for other western Atlantic areas.

With the decrease in the rate of sea-level rise at about 3000 yrs B.P. to just under 1 m per millennium, the peat accumulations stabilized resulting in the net erosion of island shores with a concomitant reduction in the area of living mangrove cover.

Consequently, a bank of relict peat was left stranded on the seafloor off the largest (northeastern) island of Tobacco Range. At present, the east coast of this island is slowly accreting windward with the vegetation (mostly the red mangrove *Rhizophora mangle*) growing over water-borne particulate matter that is being deposited along this coastline. In contrast, the leeward western shoreline is being actively eroded (Woodroffe, 1995, this volume). *Avicennia* woodland is now exposed along the broad west fringe of the range, fronted by the eroded peat surface. As mentioned, this area is subject to substantial swell under northwesterly winds and will continue to retreat (Woodroffe, 1995, this volume). The entire western limb of the southwestern island of Tobacco Range also has undergone retreat; there are numerous dead *Avicennia* stumps, perhaps initially damaged by Hurricane Hattie. Locally, *Rhizophora* seedlings have established on the lagoonward shore of this part of the range, but their establishment probably is insufficient to reverse the general regression.

Different plant communities have flourished throughout Tobacco Range's habitats and history and include (Woodroffe, 1995, this volume): *Avicennia* woodland (up to 6-8 m high), mixed *Avicennia* and *Rhizophora* open woodlands (> 4 m high), *Rhizophora* woodlands (> 4 m high), *Rhizophora* thickets (2-4 m high), *Rhizophora* scrub lands (< 2 m high), and unvegetated flats. *Rhizophora* thickets are characteristic of the outer margins of most of the islands. *Avicennia* woodlands typically occur in the center of islands, generally on substrates that are less frequently flooded than those beneath *Rhizophora*; however, to the northwest *Avicennia* woodlands have been exposed on the margin by extensive erosion. Mixed *Avicennia* and *Rhizophora* open woodlands are found throughout most of the island interiors and are transitional between *Rhizophora*-dominated and *Avicennia*-dominated vegetational types. *Rhizophora* scrub lands also occur near the centers of islands and, except where bisected by creeks, inhabit areas that appear to have been stripped of previous vegetation relatively recently.

Such vegetational differences partially account for the heterogeneity of ash and trace element contents found in the various fossil peat cores taken from the northeast island. The core samples showed alternation of layers of low and high ash content, which was interpreted (Cameron and Palmer, 1995, this volume) as reflective of cycles of rapid growth (low ash) versus periods of mangrove destruction and decomposition (high ash). The average ash contents in the deeper more-decomposed peat samples are generally greater than in the shallower coarse-fibered peat; also, peat cores from the interior of the island tend to be higher in ash than those at the edges of the island. The concentrations of some elements in the Tobacco Range peats are strikingly similar (Cameron and Palmer, 1995, this volume) to those in freshwater peats of Sumatra. The elements S, Ba, Na, Br, and Sr, but not Rb, are significantly higher in the Tobacco Range peats than in the Indonesian peats, which suggests that most were added to the dead plant remains during the

depositional process and were not accumulated during active growth. Most of the mean concentrations of other elements also are similar to the Indonesian peats within a factor of two. This probably indicates that the Tobacco Range peats like the Sumatra deposits have had a terrestrial input of elements from water-borne sediments, volcanic dust, and pumice, which even today wash up on the shores.

Littler et al. (1995, this volume) posited that hydrostatic intrusion has led to aerobic decomposition and erosion of the thick sections of fine-fibered peat overlying the Pleistocene carbonate sea-floor base off the west coast of the northeast island. This has caused an extensive undercutting of the more-resistant overlying coarse-fibered peat and, hypothetically, has produced the extensive fracturing and slumping of the peat deposits; i.e., the spectacular sea-floor relief observed (see Frontispiece, this volume). This unusual marine landscape consists of vertical submarine peat exposures, tilted slumping blocks of fossil peat, deep holes, and long narrow fractures. The upper edges of the exposed vertical walls are composed of a 10 to 20 cm-thick veneer of a living *Thalassia testudinum* community atop a 1 to 7 m-thick consolidated layer of fossil mangrove peat. This seagrass-dominated peat surface slopes westward to its point of lowest relief (<1.0 m thick, 300 to 500 m offshore) and contains poorly sorted sandy gravels and gravelly carbonate sands (mostly mollusc and foraminiferan fragments) on the unfractured surfaces, and muddy calcareous peat sediments within the fracture depressions (Littler et al., 1995, this volume). The breadth of the fractures varies from narrow fissures only 0.1 m in width to over 30 m across. Fractures nearest the island tend to be at right angles to the shoreline, dendritic or digital, and less weathered than those farther seaward. Fractures toward the northeast and southwest extreme ends of the system retain vertical or undercut walls up to 7-m thick along their entire perimeters (see Frontispiece, this volume), whereas the more central fractures tend to have collapsed outer walls with subdued weathered relief. Most of the slumped blocks contain sparse *T. testudinum* beds identifying their upper surfaces and have been tilted at chaotic angles ranging from horizontal to 35°. Multiple levels, platforms, and undercuts are conspicuous along most of the vertical walls revealing the preservation of a strongly bedded zonational pattern in the peat.

The Tobacco Range fracture zone has provided some unusual habitats for marine organisms (Littler et al., 1995, this volume). In general, the overall biota is sparse, consisting of typical members of the *Thalassia testudinum* seagrass community plus certain unusual elements. Sixty three species of marine macrophytes (61 algae and 2 vascular plants) were found (Littler, Littler, and Brooks, 1995, this volume) in the habitats within and surrounding the fractured peat zone. Of the macroalgae, 35 are Chlorophyta (greens), 22 Rhodophyta (reds), and 4 Phaeophyta (browns); 14 taxa are new records for Belize. The sedimentary bottoms of the fractures contain eight unique species, all of which are psammophytic Chlorophyta, not documented on the

vertical fracture walls or surrounding seagrass habitat. The fracture walls support 4 Chlorophyta and 2 Rhodophyta not collected in samples from the fracture bottoms or seagrass beds; whereas, the adjacent seagrass beds include 12 Rhodophyta and 3 Chlorophyta that did not occur in samples from the fractured peat habitats. Nine Chlorophyta, two Phaeophyta, and one Rhodophyta are common to all three habitat types. Between-fracture floristic differences are minor and related to the age and size of the fractures. Because of a conspicuous reduction in macrophytic cover and a shift to domination by slower-growing calcareous rhizophytic forms, Littler, Littler, and Brooks (1995, this volume) hypothesized that the fracturing process has resulted in a considerable loss to total ecosystem primary productivity. The unusual elements of the fractures appear to be in response to: (1) new spatial heterogeneity adding increased surface area and shelter, (2) diverse sedimentary substrates utilized by psammobiotic forms, and (3) a trapping effect that concentrates large mobile gastropods. This last occurrence has resulted in a phenomenon termed "interior halos" of barren sediments, since the physical bioturbation (plowing action) by these large animals apparently has eliminated rooted plant life and other sessile organisms along the perimeters of the slump depressions at the bases of the vertical peat walls.

The peat slurry between the slumped blocks of coarse-fibered peat at the innermost limits of slumping, the presence of escaping stained humic waters in conjunction with the undercut peat exposures at the lowest depositional levels, the partially decomposed sections of fine-fibered peat found in cores adjacent to slumping, and the interconnected dendritic slump patterns all suggest (Littler et al., 1995, this volume) that fracturing and slumping may be related to aerobic decomposition following hydrostatic exposure of the underlying fine-fibered peat. The subdued relief of the peat blocks (now overgrown by seagrass) in the broad depressions at the outer limits of slumping indicate that collapsing of submerged peat has been taking place for centuries and possibly millennia. The isolated fracture areas eventually become interconnected by additional dendritic branches, which predictably will continue to slump to form broader slump depressions.

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MANGROVE VEGETATION OF TOBACCO RANGE AND NEARBY MANGROVE RANGES, CENTRAL BELIZE BARRIER REEF

BY

C.D. WOODROFFE

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MANGROVE VEGETATION OF TOBACCO RANGE AND NEARBY MANGROVE RANGES, CENTRAL BELIZE BARRIER REEF

Colin D. Woodroffe*

The Belize barrier reef runs 200 km south from Ambergris Cay in the north, along the eastern coast of Belize, to the Gulf of Honduras in the south. There are numerous islands on the reef, and these can be divided into three broad types: sand cays, mangrove-sand cays, and mangrove cays (Vermeer, 1959, 1963). These types have been described in detail by Stoddart et al. (1982), who extended them into eleven types: i) Unvegetated sand cay, ii) Vegetated sand cay, iii) Unvegetated shingle cay, iv) Vegetated shingle cay, v) Sand and shingle cay, vi) Mangrove cay, vii) Shelf island (elongate islands of the northern shelf), viii) Mangrove cay with dry sand areas, ix) Mangrove range, x) Moat island (similar to the low wooded islands of the Great Barrier Reef), and xi) Coastal barrier island (barrier beaches associated with the mainland coast).

This paper examines the mangrove vegetation of Tobacco Range and nearby mangrove ranges in the central barrier reef. Mangrove ranges are elliptical mangrove islands or groups of mangrove islands. They are generally found on the broad outer barrier-reef platform, several hundred metres leeward of the reef crest (Fig. 1).

Area of study

The central Belize barrier reef consists of a shallow outer barrier-reef platform, less than 10m deep, separated from the coast by a deeper lagoon. Tidal range is microtidal, mean range at Carrie Bow is 15 cm, and tides are of a mixed semidiurnal type (Kjerfve et al., 1982).

The mangrove ranges which were studied in detail are Tobacco Range, Twin Cays (also known as Water Range), and Blue Ground Range. Tobacco Range is the largest of these. It is located about 2 km leeward of Tobacco Cay and the reef crest (Rützler and Macintyre, 1982; Macintyre et al., 1987). It is approximately 4 km long and 1.7 km wide, and has a central lagoon, generally around 2 m deep. Apart from four small pockets of coconut palms, Tobacco Range is entirely covered by mangrove vegetation. It consists of one large northern island, the interior of which contains shallow interior lagoons and areas of sparse or low mangrove; two long, narrow islands to the south; and a series of smaller islands fringing the central lagoon. The range is underlain by mangrove peat; this was found to be more than 7 m deep in a vibracore on transect IIIb. Not only does peat underlie the island, but it also continues west of the island (I.G. Macintyre, pers. comm.), where the mangrove fringe has undergone recession (i.e. see on transect IIa, Fig. 3). The central lagoon is floored by calcareous mud and sand, but in several places this was found to be underlain by mangrove peat.

Twin Cays lies about 2.3 km leeward of the reef crest, northwest of South Water Cay and Carrie Bow Cay (Rützler and Macintyre, 1982). It is 1.4 km long

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and 1.1 km wide, and comprises two islands separated by a meandering creek. It is similarly underlain by mangrove peat beneath the present mangrove vegetation and the unvegetated areas of the island interior. Halimeda-rich calcareous shelly mud or sand is found in the bed of the major creeks dissecting this range; mangrove peat has not been encountered in the top 60 cm sampled in these channels.

Blue Ground Range is located on the leeward flank of the barrier, 6-7 km west of the reef crest. It is a particularly dissected group of mangrove islands, the entire group being more than 4 km long, and 1 km wide (Fig. 9). These islands, the largest of which is only 0.7 km long, lie amid a series of carbonate shoals composed of Halimeda-rich sand and mud. There is a deep lagoon to the north (> 11 m deep), and the islands are bisected by sinuous creeks, 2-6 m deep. Probing along transect IIa and IIb indicates that the mangrove islands are underlain by mangrove peat, but that this is underlain at 150-200 cm by Halimeda sands, similar to those that make up the adjacent shoals. The shoals to the east of Blue Ground Range (Fig. 9), show evidence that they were previously occupied by mangroves; there were a few remaining stumps in 1987, and the substrate in several places consists of a thin veneer of calcareous sand over mangrove peat.

The climate of this part of the Belize barrier reef is drier than the mainland. On the mainland, more than 2000 mm of precipitation fall annually at Dangriga (Stann Creek), with a wet season from June to October. Carrie Bow Cay appears to receive an annual rainfall of around 1000mm (Rützler and Ferraris, 1982). The prevailing winds are northeast tradewinds, though there are times in the dry season when 'northers' are experienced, low pressure systems with associated fronts bringing winds from the northwest often accompanied by strong swells (Perkins, 1983). The area is subject to hurricanes during the months July to October, and was affected by the passage of a catastrophic storm, Hurricane Hattie in 1961 (Stoddart, 1963, 1974).

Methods

Mangrove vegetation was mapped from ground survey, and by the interpretation of aerial photographs. The mangrove vegetation of Twin Cays was mapped during a field survey in March 1985. Survey was from a boat, and by extensive ground traverses. Vegetation units were mapped on black and white aerial photographs taken in the early 1970s, and using colour oblique photographs taken in 1984. A brief overflight was made to verify the initial vegetation map. Ground survey on Tobacco Range and Blue Ground Range was undertaken in January 1987, and vegetation units were delineated after the ground survey on black and white aerial photography flown in January 1975 by the Royal Air Force at a scale of 1:15,000.

A series of vegetation profile diagrams were constructed at key traverses across each of the ranges. Trees within a 2 m zone, 1 m either side of a tape laid out along the transect, were recorded on the profile diagram. Height was estimated to the nearest 0.5 m, and species were determined. Profile diagrams were drawn in order to illustrate height, density and composition of the vegetation. Dead trees were also noted where stumps could be identified, in order to investigate successional trends. Detailed data on trunk diameters and

density were derived for 40 trees in a sample of each of the major vegetation units from Twin Cays (Fig. 5), using the point-centred quarter method (Cottam and Curtis, 1956). Trunk diameter measurements were taken at breast height where possible, and otherwise were below the first branch, but in the case of Rhizophora above the highest prop root.

The vegetation profile diagrams are intended to give a visual impression of the mangrove vegetation (Figs. 3,4,6,7,8 and 10). It has been necessary to simplify areas of low dense Rhizophora, generalising tree height as less than 2 m, and often reducing tree density schematically by representing only one in five trees on the transect. In several cases, on Tobacco and Blue Ground Ranges, the vegetation on the transects in 1987 does not reflect that which was mapped from the 1975 aerial photography. This is attributed to changes which have occurred in the intervening 12 years, the most widespread of which are, i) the growth of Batis over areas mapped as unvegetated flat, ii) regrowth of Rhizophora over areas mapped as unvegetated flat, and iii) localised dieback of Avicennia.

Vegetation of mangrove ranges

The most widespread mangrove species on the three ranges is red mangrove, Rhizophora mangle L., which forms a fringe around the periphery of many of the islands. In the interior of the ranges there are extensive stands of black mangrove, Avicennia germinans (L.) L., which are exposed on the shore in some locations. There are scattered individuals of white mangrove, Laguncularia racemosa (L.) Gaertn., but it does not form the thickets that it does in other West Indian islands where there has been considerable disturbance to the mangrove vegetation. Buttonwood, Conocarpus erectus L. occurs on transects at the southern end of Blue Ground Range (Fig. 10), but otherwise is restricted in its distribution especially to sandy substrates, occurring on the spit at the southern end of Twin Cays and on the sandy beach at the southern end of Tobacco Range. Batis maritima L. is the most frequent herb found within the mangroves, being especially common over the surface of otherwise unvegetated areas; Sesuvium portulacastrum (L.) L. is found in open areas within the mangroves, and Salicornia perennis Miller and a sterile grass, either Sporobolus virginicus (L.) Kunth or Distichlis spicata (L.) Greene are occasional, as also are tufts of Fimbristylis spadicea (L.) Vahl. Only one specimen of Rhabdadenia biflora (Jacq.) Mull-Arg. was found, that was on Twin Cays; this species appears only to become important on the wetter islands to the south (Stoddart et al., 1982).

While the plants listed above are found within the mangroves, there are several other plants which occur in the small sandy areas at the southern end of these ranges. Table 1 lists all plants sighted or collected on Twin Cays. Plants recorded on the islands of the Belize barrier reef are listed by Fosberg et al., (1982), and those collected previously on Twin Cays, called Water Range in that account, have been documented by Stoddart et al., (1982). Of those listed all but three, Cladium jamaicense, Casuarina equisetifolia and Wollastonia (Wedelia) trilobata, were still there in 1985. Of the 31 plants found on Twin Cays in 1985 and listed in Table 1, 14 were new records for the island.

Five mangrove types have been recognised on the basis of dominant species and vegetation structure, principally height and density. These are:

i) Rhizophora woodland (greater than 4 m tall).
ii) Rhizophora thicket (2-4 m tall).
iii) Rhizophora scrub (less than 2 m tall).
iv) Avicennia woodland
v) Avicennia open woodland with Rhizophora

In addition to these five vegetation types, there are unvegetated (or poorly vegetated) flats on both Twin Cays and Tobacco Range. On Twin Cays these are generally bare mudflat surfaces, whereas those on Tobacco Range are often covered by a carpet of Batis. These major units are described below.

Rhizophora woodland

Stands of Rhizophora in which canopy height is generally more than 4 m are most widespread on Twin Cays, but also occur on Tobacco and Blue Ground Ranges. On Twin Cays they occur along much of the windward north and east shores and form the dominant mangrove vegetation on the two small islands at the northern end of the central channel (Fig. 5). Elsewhere this taller Rhizophora is found within the unvegetated flats of the interior, characteristically occurring at the southern end of shallow interior lagoons which characterise many of the unvegetated flats. On Tobacco Range, Rhizophora woodland occurs in a small stand at the northwestern tip of the island (Fig. 2, and transect I, Fig. 3), is found on a series of small islands in the central eastern section of the range, and forms a number of stands in the island interior. On Blue Ground Range, Rhizophora woodland is found around the outside of islands to the north of the range (Fig. 8), and on the northern end of the southernmost islands (i.e. transect VI, Fig. 10).

Rhizophora can grow up to 7-8 m tall in this unit, with trunk diameters of 25-30 cm. There are well developed prop root systems reaching more than 1 m above the ground. Some of the largest trees have formed tortuous recurved trunks which are intricately intertwined. Younger trees are generally straighter where this woodland is actively regenerating. Tree density is variable; older spreading, gnarled trees may be better spaced, but where measured there was around 4500 trees per hectare, with a basal area of 19.9 m^2 ha^{-1}. On Twin Cays, transects IV, V, VI and VII (Fig. 7 and 8) pass through Rhizophora woodland at their eastern ends. Here individual Laguncularia, up to 6 m tall, are encountered at more than 20 m from the seaward fringe within the Rhizophora woodland. Rhizophora is interspersed with Avicennia along much of the boundary between these two vegetation types; it grades gradually into Rhizophora thicket. Rhizophora woodland more than 10 m tall is found on neighbouring Man of War Cay, which supports a dense colony of frigate birds, whose droppings presumably enrich the substrate.

Rhizophora thicket

Rhizophora thicket is the most widespread mangrove type on Twin Cays, and accounts for a substantial proportion of both Tobacco and Blue Ground Ranges. On Twin Cays it forms the fringe around the islands where there is no Rhizophora woodland, and extends into the interior of the islands. On Tobacco Range it is typical of the fringe around much of the central lagoon, and also fringes much of the outside of the southwestern section of the range (Fig. 2). On

Blue Ground Range it fringes islands where Rhizophora does not reach the stature of Rhizophora woodland, and is the sole vegetation of several of the islands to the south of the range.

The general canopy is 2 to 4 m tall, though there are Rhizophora taller than 4 m and others shorter than 2 m. Prop root systems reach up into the canopy, making this the most impenetrable of mangrove types. Where density was determined this was 4790 trees per hectare, with a basal area of 13.0 m^2 ha^{-1}; however, density is extremely variable.

Rhizophora scrub

Rhizophora scrub, generally less than 2 m tall, and often less than 1 m tall, is found over extensive areas in the interior of Tobacco Range and Twin Cays, and in one broad, now dissected zone in central Blue Ground Range. Neighbouring plants are usually not entangled, making it much easier to walk through than Rhizophora thicket. Where measured density was 17500 trees per hectare with a basal area of only 7.5 m^2 ha^{-1}. However, it is evident from transects that the density can vary considerably, reaching as high as 40000 trees per hectare. Rhizophora scrub is found adjacent to the unvegetated flats in the interior of Twin Cays and in a similar setting to interior lagoons on Tobacco Range, but is rarely exposed on the margin of the islands except where the fringe has been eroded. By contrast on Blue Ground Range the main area of Rhizophora scrub is in the centre of the range (transect III, Fig. 10), but it has been bisected by channels, so that Rhizophora scrub is exposed on the banks of the channels through the range (Fig. 9).

In the densest area of this scrub, many of the Rhizophora seem to have been recently established and are little more than saplings, and stands are presumably not of any great age, and may not be able to regenerate themselves over many generations. Where older individuals are established they are recumbent, often with leaves on the ends of branches held below the highest prop root, such that these are clearly not low simply because they are young. Some environmental control appears to be limiting growth, and this is most probably a nutrient limitation (R. Twilley, pers. comm.). The transition from Rhizophora scrub to Rhizophora thicket is fairly distinct.

Avicennia woodland

Woodland in which Avicennia germinans is the major tree, covers much of Tobacco Range, and is an important element of the interior of both Twin Cays and Blue Ground Range. On Tobacco Range, Avicennia woodland is extensive along the northwestern margin, where it is clearly undergoing recession (Fig. 2), with retreat of the fringe indicated by the erosional bench in mangrove peat to seaward of the mangroves. There are also stands of Avicennia left along the eastern margin of the range. Relatively monospecific stands of Avicennia occur just landward of the windward fringing Rhizophora woodland on Twin Cays. Elsewhere low Rhizophora is common with the Avicennia, and this has been mapped as Avicennia open woodland with Rhizophora. A typical stand of Avicennia woodland occurs to the eastern end of transect IV (Fig. 7), and it

seems likely that almost pure Avicennia woodland characterised much of the area that is marked as cleared on Fig. 5. Many tall individual Avicennia are left standing in the clearing. On Blue Ground Range Avicennia woodland is restricted to the interior of islands (i.e. transects IV and V, Fig. 10). Pelicans were nesting in the Avicennia woodland on transect V (Fig. 10) in 1987.

Avicennia reaches up to 6-8 m tall with diameters of 20-30 cm, and where density was measured it was 5760 trees per hectare, with a basal area of 20.9 m^2 ha^{-1}. The presence of smaller trees indicates that this mangrove type is regenerating. The floor of this mangrove type is covered with pneumatophores 15-20 cm tall, and a spasmodic ground cover of Batis maritima. The older and larger Avicennia have large spreading canopies and appear to shade out seedlings.

Avicennia open woodland with Rhizophora

Similar to but often more widespread than Avicennia woodland are areas of Avicennia open woodland with Rhizophora. In these, Avicennia does not reach such great heights, generally less than 5 m, nor such high densities, but Rhizophora is an important element. On Tobacco Range Avicennia open woodland with Rhizophora generally occurs in the interior, but is exposed on the fringe on the western margin of the central lagoon. On Twin Cays, this is usually a vegetation type found in the interior of the range; Rhizophora is generally low, often less than 2 m tall, forming and understorey beneath Avicennia up to 5 m tall. Elsewhere, Avicennia appears to be under stress; there are many stunted, dying and dead Avicennia in the Avicennia open woodland with Rhizophora and in adjacent Rhizophora mangrove types. On Blue Ground Range Avicennia open woodland with Rhizophora forms stands in the interior of islands grading into Avicennia woodland; it is prominent on transect IIa (Fig. 10).

In the typical stand examined, the density of all trees was 6840 trees per hectare, while that of Avicennia of more than 10 cm trunk diameter was only 684 trees per hectare. Average diameter was 4.89 cm and total basal area was 20.9 m^2 ha^{-1}, similar to that for Avicennia woodland (Table 2). However the basal area for Avicennia alone was only 14.1 m^2 ha^{-1}. Though very variable the more open nature of Avicennia open woodland with Rhizophora means that Batis is widespread, and Salicornia, Sesuvium and grass occur.

Unvegetated flats

There are many areas in the interior of Tobacco Range and Twin Cays which do not carry dense mangrove vegetation. These either dry at low tide, like the Anderaa flats on Twin Cays, or may remain shallowly flooded (generally less than 50 cm deep) as do the interior lagoons mapped as open water on Tobacco Range. These bare areas often have Rhizophora scrub around them. Seawater floods through these unvegetated flats and the surface water salinity where measured on Twin Cays was 38 parts per thousand, the same as in the main channel. Seawater flows between unvegetated flats by shallow depressions, 10-20 cm below the surface of adjacent mangrove flats, forming an incipient creek

system. Where water remains over the surface there is prolific growth of marine algae.

Surface sediments are fine and largely algal-derived. These can be soft, but a firm substrate composed of mangrove peat is found at up to 50 cm below the surface in all pools traversed during this survey. Creek-floor sediments contain the empty shells of the gastropod Cerithidea.

Many of the areas clearly unvegetated and mapped as unvegetated from the 1975 aerial photography, carried a cover of Batis, or in places regrowth of mangroves, particularly Rhizophora, when surveyed in 1985 or 1987.

Belize mangrove forests in a regional context

Mangrove forests of the New World (and West Africa) are structurally and floristically less complex than those of the Old World (Chapman, 1975). Many of the mangrove forests of the mainland coastline of Central America are in areas receiving a large terrestrial sediment input and are developed over muds (Thom, 1967; West, 1977). Such terrigenous-substrate mangrove forests cover much of the coast of mainland Belize (Wright et al., 1959). On the mangrove ranges of the Belize barrier reef, on the other hand, beyond the influence of terrestrial sediment, the mangrove forests are underlain by mangrove-derived peat. These peats are highly organic (loss on ignition 65-75%).

Mangrove forests developed over an organic, peaty substrate, are found in several carbonate settings in the West Indies. They are extensive in southwestern Florida (Davis, 1940; Gleason et al., 1974; Turmel and Swanson, 1976), Cayman Islands (Woodroffe, 1981) and Jamaica (Digerfeldt and Hendry, 1987). In contrast to their muddy counterparts, a diverse marine biota characterises the prop roots of Rhizophora which hang into deep water in the meandering creeks. Similar mangrove ecosystems have been described from Brazil (Gerlach, 1958), Puerto Rico (Mattox, 1949), and the Bahamas (Howard, 1950; Rützler, 1969).

The structure of mangrove forests in Florida, Puerto Rico, Costa Rica and Mexico has been reviewed by Pool et al. (1977). They classify mangrove types into five classes: i) fringe mangrove, fringing open seawater and frequently flooded by tides; ii) basin mangrove, interior mangrove less frequently flooded; iii) overwash mangrove, completely overwashed by tides; iv) scrub mangrove, dwarfed forms of mangrove; and v) riverine mangrove, mangrove influenced by riverine freshwater input.

In topographic terms much of the mangrove forest on these Belize mangrove ranges would fall into the overwash category of Pool et al. (1977), because the smaller islands are entirely overwashed at the highest tides. However elevational data and observations in March 1985 indicate that Avicennia woodland on Twin Cays is infrequently inundated, and many of the islands may have passed beyond the overwash stage. Where islands are not of the overwash category, Rhizophora woodland of the windward margin of the island may be described as fringe mangrove; much of the interior Avicennia woodland, or Avicennia open woodland with Rhizophora falls into the basin mangrove category of Pool et al. (1977); and Rhizophora scrub is equivalent to the scrub mangrove category.

Table 2 records the structural parameters of the five mangrove types on Twin Cays. These are not directly comparable with the parameters used by Pool et al. (1977), because they only considered trees with diameters greater than 2.5 cm. This was not felt appropriate in this study because so many trees are less than this diameter (mean diameter in Rhizophora scrub was 2.25 cm). Accordingly, individuals that were larger than recently established saplings were included (those trees less than 2.5 cm diameter, however, contribute very little to the total basal area, but their inclusion will make a difference to measures of tree density). Rhizophora scrub of Twin Cays is very similar to scrub Rhizophora described by Pool et al. (1977) from Turkey Point, Florida, with a density of 17400 trees per hectare, and a basal area of 7.5 m^2 ha^{-1} in the former, and 25030 trees per hectare and 6.0 m^2 ha^{-1} respectively in the latter. These values for density are within the wide range of density evident in this mangrove type from the transects. Scrub Rhizophora has also been reported from basins in the interior of Little Cayman (Stoddart 1980), and around the eastern margin of North Sound, Grand Cayman (Woodroffe, 1981; Brunt, 1984).

The most similar sites to the other mangrove forests on Twin Cays, from all of those recorded by Pool et al. (1977), were a basin mangrove in Rookery Bay, Florida and a fringe mangrove in Ceiba, Puerto Rico. Particularly similar mangrove forests have been described from several parts of Puerto Rico by Cintron et al. (1978) and Zucca (1982).

Stability and change in the vegetation of mangrove ranges

The pattern of mangrove zonation, typical throughout most of the New World mangrove forests, of seaward Rhizophora replaced to landward by Avicennia, is not found throughout the mangrove ranges of the central Belize barrier reef. While this arrangement does characterise the eastern fringe of Twin Cays (i.e. eastern transect IV, Fig. 7) and several of the small islands on Blue Ground Range (i.e. transects IV and V, Fig. 10), there are many areas where Avicennia is exposed on the seaward margin (i.e. transect IIa, Tobacco Range, Fig. 3), or extensive stands of Rhizophora occur throughout the interior of islands.

There is also abundant evidence that the pattern of distribution is changing. This is shown in particular by the extensive unvegetated flats which characterise the interiors of Tobacco Range and Twin Cays, and the dead mangrove stumps which occur throughout each island and have been mapped along the transects. Particularly prominent are the dead stumps of Avicennia, truncated close to the mudflat surface, within either bare or Rhizophora scrub areas of Tobacco Range and Twin Cays.

There are three explanations which can be offered to account for the dieback of Avicennia: hurricane damage, environmental stress, or human clearance. The suggestion that this is the result of hurricane damage, has considerable appeal, because catastrophic storms are known to have had a devastating effect on the topography and vegetation of islands of the Belize barrier reef. Hurricane Hattie which struck the reef in 1961, passing to the north of the study area, is known to have caused extensive mortality of mangroves (Vermeer, 1963; Stoddart, 1963, 1965, 1971, 1974). Defoliation of Rhizophora was widespread; but relatively few observations were made of the storms effect

on Avicennia, or recovery of this species. A large area of devastation at the southern end of Tobacco Range is attributed to Hurricane Hattie by Stoddart et al. (1982) and has changed little since 1972, as shown in their plate 70.

There are several reasons to suppose that environmental factors could pose a limitation on mangrove distribution and be responsible for mortality of one species and its replacement by another. Firstly the fairly clearly defined vegetation units composed of either Rhizophora or Avicennia suggest some underlying environmental factors which control the successful establishment of propagules of either species at a specific site. Surveying across northern Twin Cays, as well as at selected sites on the other ranges, has suggested an elevational range of only around 15 cm over which mangrove forests occur, though with a tendency for Avicennia to occur only in the higher locations.

Salinity is one factor which appears to control mangrove distribution elsewhere, and high salinities in low rainfall areas account for the occurrence of bare mudflats within or landward of mangrove forests (Fosberg, 1961; Giglioli and King, 1966; Spenceley, 1977). Cintron et al. (1978) have described mangrove forests from the arid south coasts of Puerto Rico. They suggest that dieback of mangroves occurs in the interior of small annular islands as a result of high salt concentrations. In their study they recorded a mean salinity of 44 parts per thousand beneath live trees, 72 parts per thousand beneath dead trees, and 87 parts per thousand beneath interior unvegetated flats. They indicated rapid mortality of mangroves where salinities were more than 65 parts per thousand, and intolerance to salinities in excess of 90 parts per thousand.

West (1977) has attributed bare areas in the interior of Ambergris Cay to hypersalinity, and suggested that this might also explain bare areas on other Belizean mangrove cays. On Twin Cays measurements of salinity of water standing over unvegetated flats in the island interior was similar to that of the open water in the central channel (38 parts per thousand). Interstitial salinity, both from water draining into a core hole from Twin Cays, and from water squeezed from soil at depth, did not reach the high salinities reported by Cintron et al. (1978) from Puerto Rico. The highest salinity recorded was 58 parts per thousand which was beneath apparently healthy, regenerating Avicennia woodland. In the unvegetated flat salinities at 25 cm and at 45 cm below the surface were 47 parts per thousand. These measurements were made during low neap tide in March which is usually the driest month of the year. This is the time of the year at which soil salinities have been shown to be at their highest (40-50 parts per thousand) in mangrove substrates in Laguna de Terminos in Mexico (Day et al., 1987), and when they might also be expected to be at a maximum on Twin Cays. The surface of most if not all of each of the mangrove ranges gets flooded by the the highest spring tides, and frequent flooding by seawater is likely to dilute interstitial salinities and prevent hypersalinity building up. There seems little reason to suspect that, even in drought years, salinity in the substrate of these mangrove ranges builds up to levels which would cause mangrove mortality. Another important difference between mangrove dieback on these ranges and that reported from Puerto Rico (Cintron et al., 1978) is that dieback of Avicennia, especially on Twin Cays, appears to have been followed by colonisation by Rhizophora, which is generally less tolerant of high salinity.

It is possible that other environmental factors account for the mangrove dieback. On salt marshes, sulphide levels, ion toxicity or nutrient deficiencies

have each been implicated as causes of dieback (Mendelssohn et al., 1982). On Twin Cays measurements of Eh and sulphide concentrations of the sediment indicates that is partly a function of the vegetation, and the plants themselves may serve to aerate the sediment as well as aeration through the burrowing activity of crabs and other invertebrates (McKee et al., 1988). The higher sulphide levels under unvegetated flats would not appear to inhibit mangrove growth there. While these and other environmental factors may effect the performance of mangrove species, neither the salinities, nor the other factors can be directly linked to mangrove mortality.

The third explanation, deliberate clearing of mangroves, has occurred locally on many of the islands on the Belize barrier reef, especially to enable the construction of buildings on the cays. However, there is no logical explanation for the widescale and disorganised clearing which would be implied, if all unvegetated areas were attributed to human action. There seems little doubt that the majority of those areas mapped as cleared, or unvegetated, on the vegetation maps, are the result of natural and not anthropogenic factors.

Tree stumps, and broad unvegetated areas are most extensive on Tobacco Range and Twin Cays; there are no areas mapped as unvegetated on Blue Ground Range, although the presence of isolated mangrove stumps and mangrove peat on the shoals to the east of the range indicate relatively recent mangrove recession. Hurricane Hattie is known to have caused mortality of mangroves further north along the Belize barrier reef, and it seems most likely that it also had a devastating effect on parts of Tobacco Range and Twin Cays. Avicennia in many of the bare areas, and those areas now recolonised by low Rhizophora scrub may have been truncated as a result of Hurricane Hattie. Rhizophora too may have undergone extensive mortality as a result of the storm, but except for the stumps which do occur as shown on the transects (not all of which resulted from the single storm event), may now be less clear as Rhizophora appears to rot back more rapidly, and many stumps are now truncated below ground level and the only evidence are the sheaths of the roots.

While the tree stumps and bare areas provide evidence of recent mangrove dieback, there is also evidence of a longer term decrease in mangrove area. Mangrove forests appear to have established on the Belizean barrier reef as soon as the previous subaerially-exposed surface was flooded by rising sea level during the Holocene transgression. Mangrove peat has been encountered at the base of numerous cores through Holocene sediments across the barrier reef (Purdy, 1974; Shinn et al., 1982). At Boo Bee Patch reef, just south of the study area, drilling has shown that a Pleistocene patch reef morphology, upon which a Holocene patch reef has been established, is surrounded by basal peat of presumed mangrove origin dated about 8000 years B.P. (Halley et al., 1977). The final stage of the transgression is recorded in mangrove peat deposits on Ambergris Cay, where a basal soil unit is overlain by mangrove peat, in turn overlain by calcareous sediments locally recording regression with lateral extension of the island environments (Ebanks, 1967, 1975).

Purdy (1974) has shown from numerous seismic traverses that many of the present islands on the Belize barrier reef are located over Pleistocene topographic highs. Mangrove ranges may also be located over topographically high points in the underlying Pleistocene limestones, as has been suggested by Stoddart et al. (1982). Results from vibracoring undertaken by I.G. Macintyre and others

indicate that Tobacco Range and Twin Cays were formerly more extensive. The present mangrove ranges appear therefore to represent all that remains of a more extensive early-mid Holocene mangrove forest, preserved because of their relative shelter behind windward reef crests.

There is abundant evidence that all three mangrove ranges are continuing to undergo recession. Erosion of the shoreline is especially pronounced along the northwest of Tobacco Range, where Avicennia woodland is now exposed along a broad fringe of the range, fronted by an eroded peat surface. This area is subject to substantial swell under a northwesterly wind, and will continue to retreat. The entire western limb of the southwestern island of Tobacco Range, has undergone retreat; there are numerous dead Avicennia stumps, perhaps initially killed by Hurricane Hattie, and the surface has continued to erode. Locally Rhizophora seedlings have established on the lagoonward shore of this part of the range, but their establishment is insufficient to reverse the general recession of this part of the shore.

The meandering creeks or bogues which dissect the ranges also appear to be erosional. They are fringed by Rhizophora, beneath the prop roots of which there is a scarp, or overhang in the mangrove peat. Occasionally the undercutting is so extensive that there is collapse of mangroves into the creek. Shallow creeks have incised into the surface, particularly of Twin Cays, connecting interior lagoons to the larger creeks. This appears to be a process by which the ranges are slowly fragmented. The central lagoon of Tobacco Range may similarly be an erosional feature. Shallow cores to the north revealed mangrove peat below the calcareous sediments which comprised the lagoon floor, but probing elsewhere did not reveal a similar sequence in the top metre of sediment. Blue Ground Range has undergone some retreat on its eastern margin, but elsewhere the consistent Rhizophora fringe around most islands suggests little recent change. The Rhizophora scrub belt in the centre of Blue Ground Range is interpreted as having been dissected by the creek system.

Many accounts of the geomorphological role of mangroves have implied that they have the ability to colonise new intertidal habitats, and to 'reclaim land from the sea'. There is now a large body of evidence to demonstrate that this is not always the case (Thom, 1975; Woodroffe, 1983). Fragmentation of mangrove ranges on the Belize barrier reef appears to be yet another instance where mangrove forests are undergoing net decrease, rather than increase, of area.

Discussion

Gradual disintegration of mangrove forests on the Belize shelf occurred during the Holocene transgression as the sea rose from tens of metres below present to reach its present level. This has resulted in a transgressive sedimentary sequence, with mangrove peat recorded above soil, or freshwater peat deposits, from sites around the Gulf of Mexico (Scholl, 1964; Gleason et al., 1974; Ebanks, 1975; Woodroffe, 1981, 1982; Hendry and Digerfeldt, 1989). The seaward margin of the mangrove forests also retreated landwards, especially during those times when sea level was rising most rapidly, and progradation has

only been possible since sea-level rise has decelerated to less than 2 mm yr^{-1} (Parkinson, 1989).

It needs to be considered whether mangrove dieback observed during mapping of the Belize mangrove ranges might be due to ongoing, or accelerated, sea-level rise. There is presently concern that the sea is rising, and that coastal wetlands may be particularly vulnerable to drowning (Bird, 1993). Such accelerated rise might see mangrove shorelines, such as those in the Everglades, reverting to conditions typical of mid Holocene times when there was a faster rate of relative sea-level rise (Wanless and Parkinson, 1989).

Mangrove forests which do not receive a terrigenous sediment input, and which are consequently underlain by mangrove-derived peat, are likely to be the most susceptible to drowning (Woodroffe, 1988, 1990; Ellison and Stoddart, 1991). Ongoing retreat of the mangrove fringe in Bermuda has been attributed to rapid sea-level rise (Ellison, 1993). The great depth of peat beneath the Belize ranges, and radiocarbon dates from Tobacco Range and other parts of Belize, however, indicate that vertical accretion of peat did keep pace, at least in some places, with rates of mid-Holocene sea-level rise of 4.5 mm yr^{-1} or more (I.G. Macintyre, pers. comm.).

The recent dieback of mangroves on Tobacco Range and nearby mangrove ranges, superficially resembles the situation which might be expected if sea level were to rise at a rate faster than that at which the substrate could accrete. Shoreline erosion, and death of inland mangrove species and their replacement by more seaward species has been predicted under such circumstances (Woodroffe, 1990). There are, however, a number of reasons for attributing this dieback to storm damage. First, although much of the shoreline of the mangrove ranges is presently being eroded, erosion is generally along those shorelines which are periodically exposed to large waves, and is not universal. In many places there is a pronounced erosional cliff over which Rhizophora roots hang, and there seems no reason why such cliffing should be a feature of gradual sea-level rise. Within the mangrove ranges mortality of mangroves shows no clear spatial pattern in relation to the mangrove types mapped. There is little evidence for death of mangroves in the few years prior to survey, and no signs of ongoing stress; the stumps are preferentially of large trees, which died simultaneously some time ago, and have since been truncated close to ground level. Where profiles were surveyed, as on Twin Cays, there was no indication that death had occurred primarily amongst those trees rooted at the lowest elevations as might be expected if there had been landwards encroachment of Rhizophora into Avicennia which might reflect sea-level rise. Dead Rhizophora and Avicennia are often intermixed.

Further evidence in support of storm damage is the gradient in extent of damage from north to south. The greatest mortality, measured as trees per metre of transect surveyed, occurred on Tobacco Range, and the least was observed on Blue Ground Range. This gradient away from the path of Hurricane Hattie lends further support to the conclusion that the dieback occurred as a result of storm damage. In this case the known history of a devastating storm, reports of widespread storm damage in the area (ie. Stoddart et al., 1982), and the little change which has occurred since the 1972 or 1975 photography, support the contention that mangrove dieback occurred on these ranges primarily as a result

of storm damage. Nevertheless, it may be difficult to differentiate the cause of dieback in other cases, and this example serves to illustrate that dieback of mangroves could be attributed to other factors, such as the effects of sea-level rise, where these may not have had a major impact on mangroves over recent decades.

Conclusion

The mangrove vegetation of Tobacco Range, Twin Cays and Blue Ground Range has been mapped into five mangrove types: Rhizophora woodland (>4 m tall), Rhizophora thicket (2-4 m tall), Rhizophora scrub (<2 m tall), Avicennia woodland, and Avicennia open woodland with Rhizophora. Rhizophora woodland or Rhizophora thicket is characteristic of the margins of most of the ranges. Avicennia woodland typically occurs in the centre of islands, generally on substrate that is less frequently flooded than that beneath Rhizophora; however, to the northwest of the northern ranges it has been exposed on the margin by erosion. Avicennia open woodland with Rhizophora is found in much of the interior transitional between pure Rhizophora and pure Avicennia vegetation types. Rhizophora scrub occurs in the centre of ranges, covering areas that appear to have been stripped of prior vegetation relatively recently. It is restricted to the centre of ranges except where creeks have bisected them. There are also extensive unvegetated flats in the interior of Tobacco Range and Twin Cays.

Mangrove ranges have built up over a substrate of mangrove-derived peat, perhaps over topographic highs in the underlying Pleistocene surface, and many of them appear to have persisted since the development of widespread mangrove forests over the Belize barrier reef during the Holocene transgression. The ranges have been undergoing disintegration; peat, which is encountered beneath adjacent shoals, exposed by shoreline erosion, or found in creeks and lagoons within the range, testifies to the greater extent of mangrove cover relatively recently. Creeks, or bogues, are bisecting the ranges and appear to be an important element in the gradual disintegration of these islands.

Extensive mortality of mangroves has occurred recently, and in places shoreline erosion may be continuing. The extensive unvegetated flats on Tobacco Range and Twin Cays, and the widespread dead tree stumps found throughout these ranges, are probably the result of damage during Hurricane Hattie which devastated much of the barrier reef to the north in 1961. Catastrophic storms are evidently an important factor in accounting for the present vegetation distribution on these mangrove ranges, and contribute significantly to the longer term disintegration of these islands.

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TABLE 1: Plants recorded on Twin Cays, March 1985.

Plant species	Collection number (deposited at the Smithsonian Institution)
Eleusine indica (L.) Gaertn.	620
* Eustachys petraea (Sw.) Desv.	616
* Paspalum distichum L.	612
Spartina patens (Ait.) Muhl.	624
* Sporobolus virginicus (L.) Kunth or Distichlis spicata (L.) Greene	601
Cyperus ligularis L.	611
Cyperus peruvianus (Lam.) Williams	618
* Cyperus planifolius L.C.Rich	623
Fimbristylis cymosa R.Br. var. spathacea (Roth)Koyama	619
Fimbristylis spadicea (L.) Vahl	605
* Cocos nucifera L.	sight
* Thrinax radiata Lodd. ex Schultes & Schultes	sight
* Batis maritima L.	633
* Salicornia perennis Miller	628
Philoxerus vermicularis (L.) Beauv.	615
Sesuvium portulacastrum (L.) L.	608
Cakile lanceolata (Willd.) O.E. Schulz	610
* Suriana maritima L.	625
* Euphorbia mesembrianthemifolia Jacq.	614, 632
* Rhizophora mangle L.	634
* Conocarpus erectus L.	607, 627
* Laguncularia racemosa (L.) Gaertn. f.	636
Rhabdadenia biflora (Jacq.) Mull.-Arg.	602
Ipomoea pes-caprae ssp. brasiliensis (L.)V.Ooststr.	609
* Avicennia germinans (L.)L.	635
* Erithalis fruticosa L.	626
* Ageratum littorale A. Gray	617, 622 631
* Borrichia arborescens (L.) DC.	603
Eclipta alba (L.) Hassk.	606
Eclipta cf. prostrata (L.) L.	621
Vernonia cinerea (L.) Less.	604

* recorded from Twin Cays in 1972 (Stoddart et al. 1982)

Table 2 Structural characteristics of mangrove types on Twin Cays.

Sample Number	Mangrove Type	Canopy Height (m)	Tree Height Mean + S.D. (m)	Density (trees/ha)	Trunk Diameter Mean + S.D. (cm)	Basal Area (m^2/ha)	Component Species	% Density	% Basal Area
1	<u>Rhizophora</u> <u>woodland</u>	5.0-6.0	4.1 +/- 1.1	4500	6.26 + /- 4.19	19.9	<u>Rhizophora</u>	95	99
							<u>Laguncularia</u>	5	1
2	<u>Rhizophora</u> <u>thicket</u>	3.0-4.0	3.0 +/- 1.0	4790	5.49 + /- 2.12	13.0	<u>Rhizophora</u>	98	>98
							<u>Laguncularia</u>	2	<2
3	<u>Rhizophora</u> <u>scrub</u>	1.0-1.5	0.8 +/- 0.2	17400	2.24 + /- 0.60	7.5	<u>Rhizophora</u>	100	100
4	<u>Avicennia</u> <u>woodland</u>	4.0-5.0	2.9 + /- 1.3	5760	5.48 + /- 4.06	20.9	<u>Avicennia</u>	92	>99
							<u>Rhizophora</u>	8	<1
5	<u>Avicennia</u> open woodland with <u>Rhizophora</u>	4.0-5.0	2.7 + /- 1.1	6840	4.89 + /-- 3.91	20.9	<u>Avicennia</u>	32	68
							<u>Rhizophora</u>	55	30
							<u>Laguncularia</u>	13	2

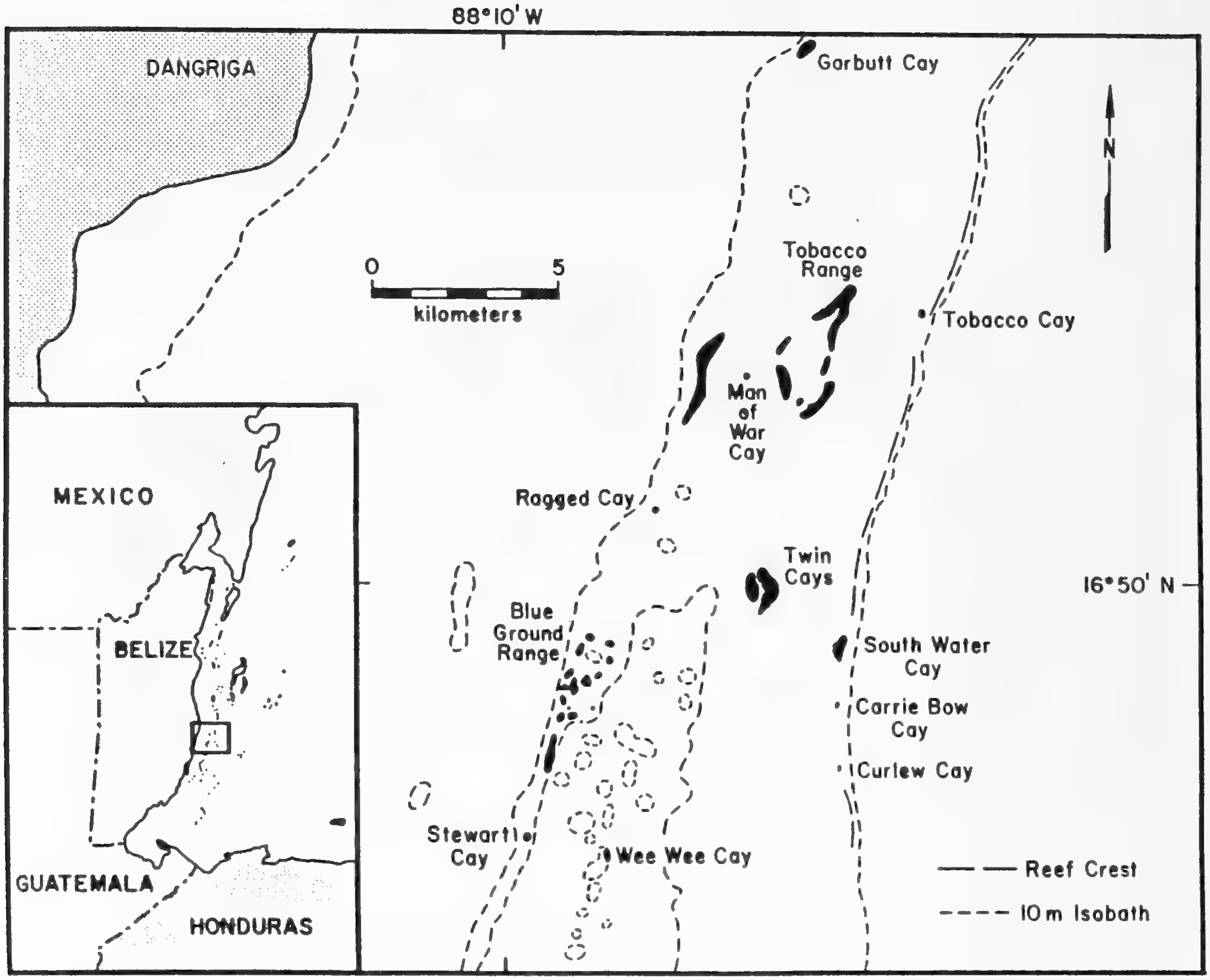

Fig. 1: The central Belize barrier reef showing the location of Tobacco Range, Twin Cays, and Blue Ground Range.

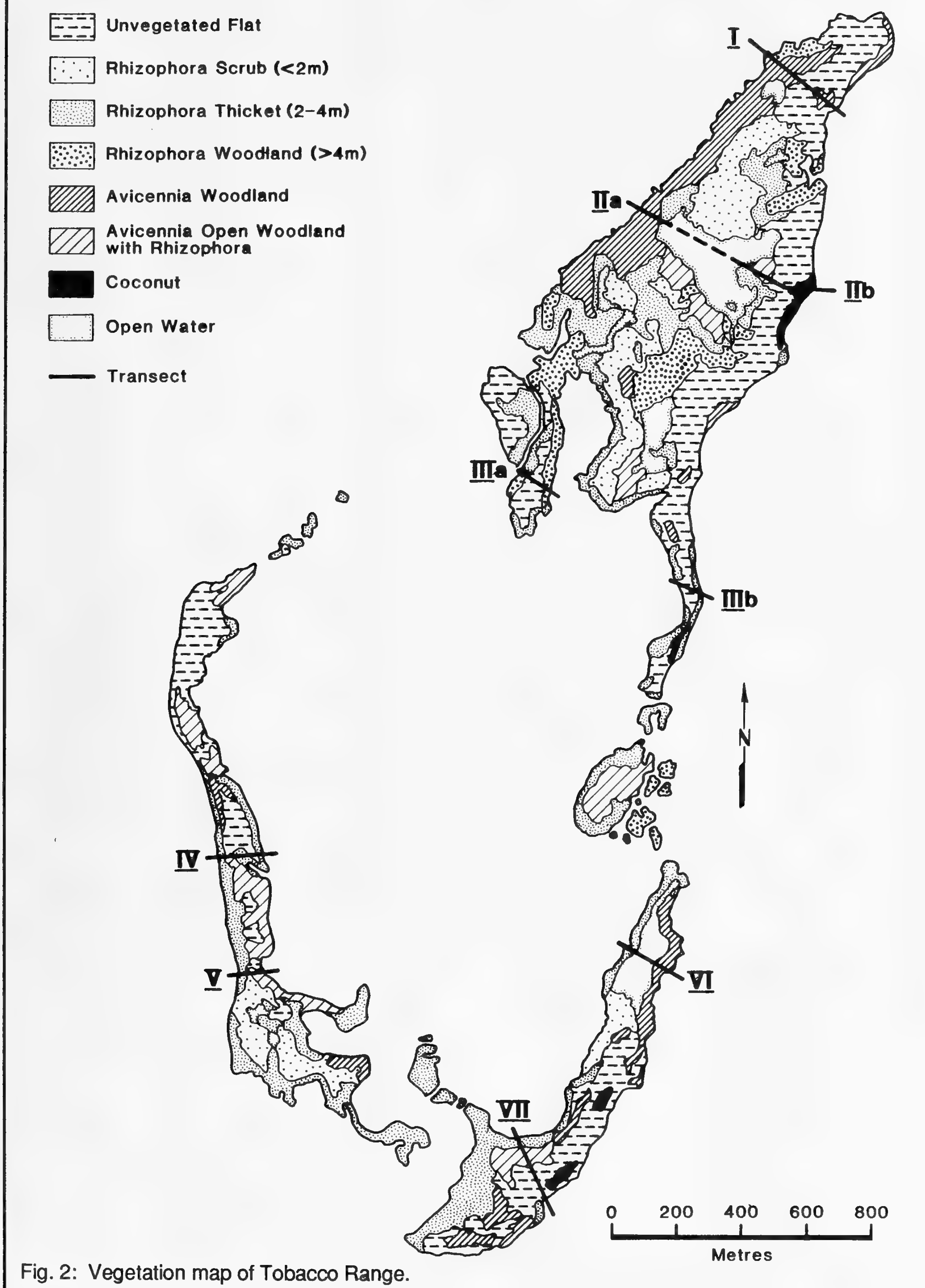

Fig. 2: Vegetation map of Tobacco Range.

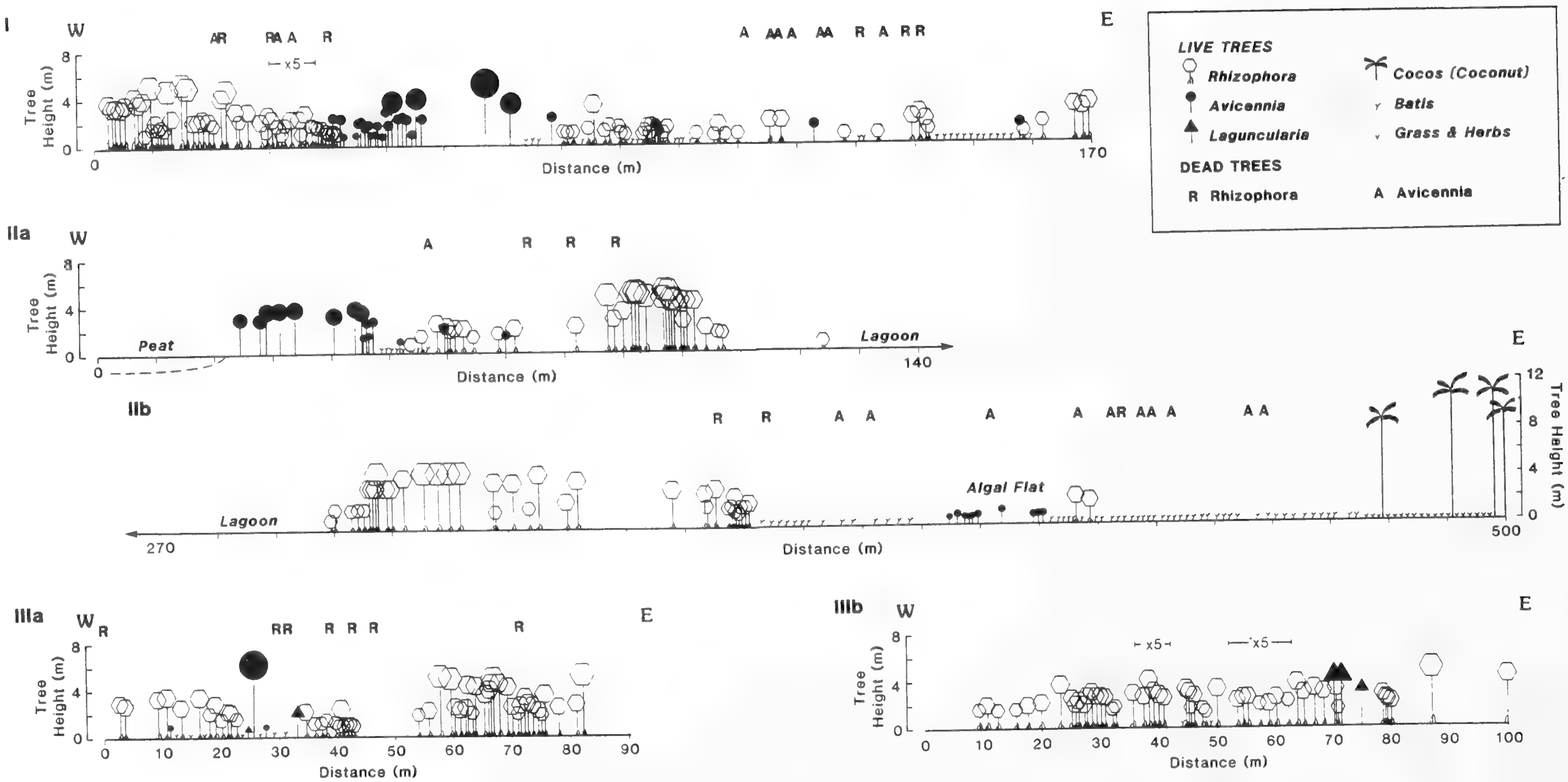

Fig. 3: Transects I-IIIb, Tobacco Range (x5 indicates that the density of Rhizophora was five times that shown on the transect).

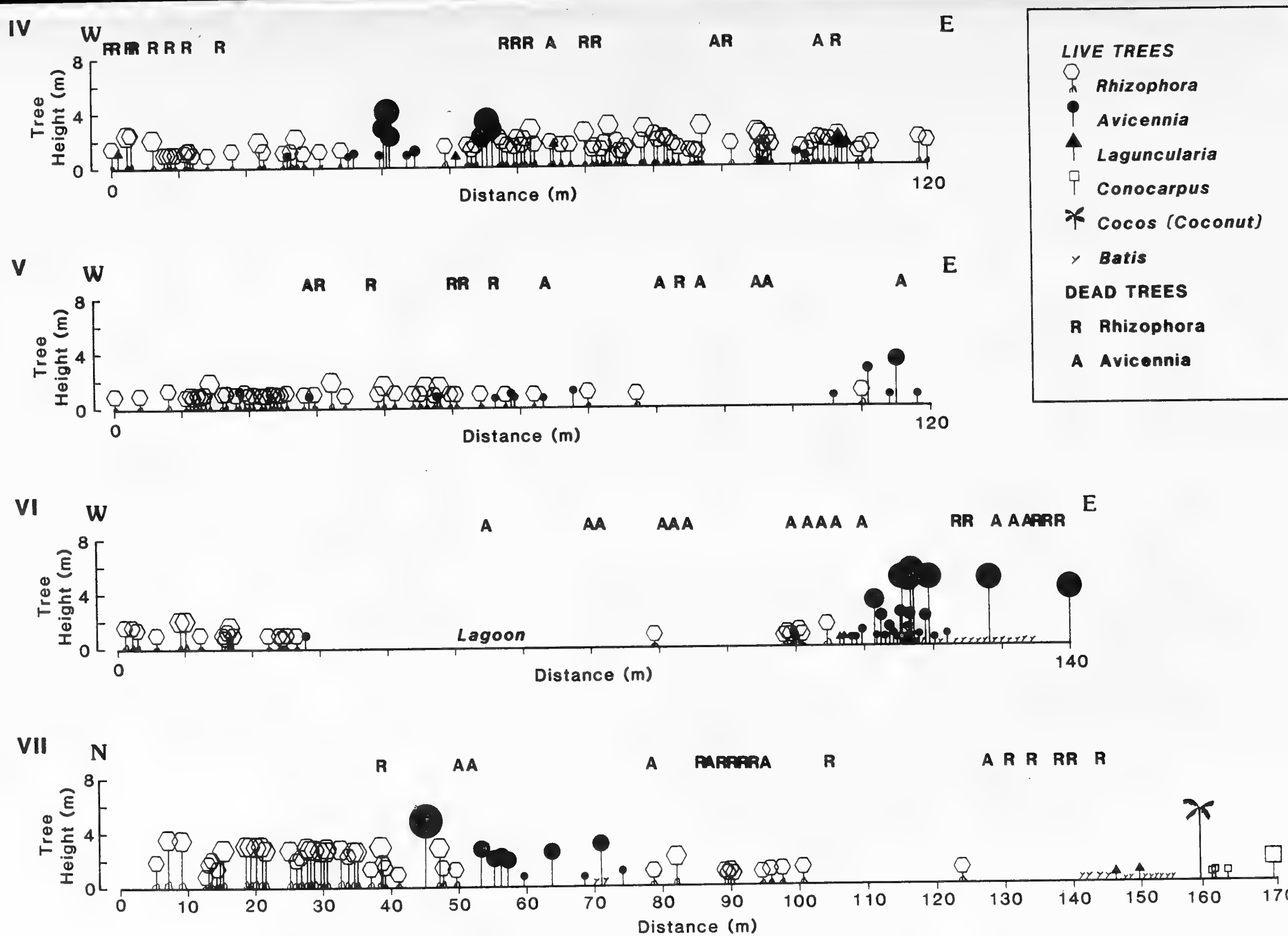

Fig. 4: Transects IV-VII, Tobacco Range (x5 indicates that the density of Rhizophora was five times that shown on the transect).

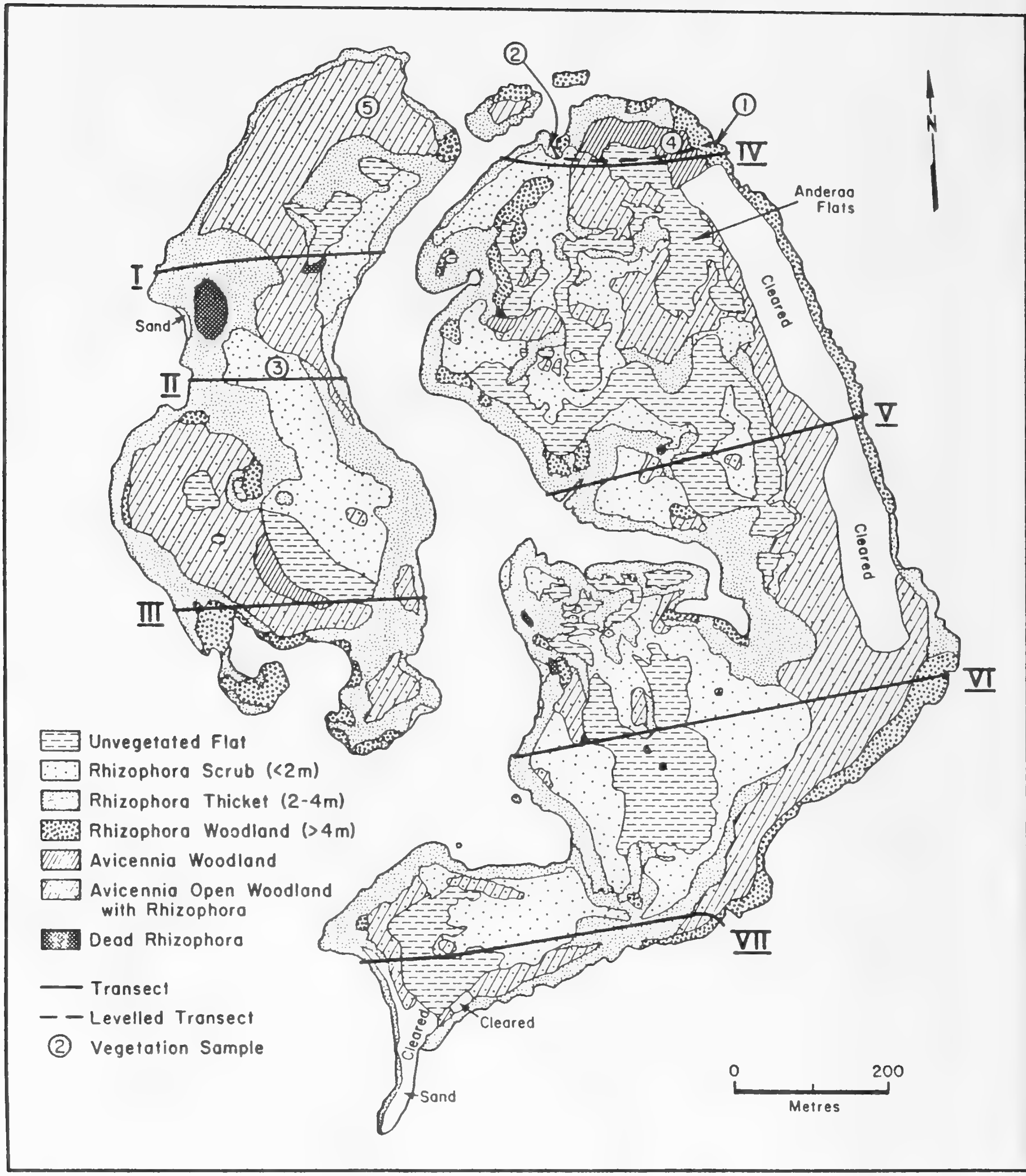

Fig. 5: Vegetation map of Twin Cays.

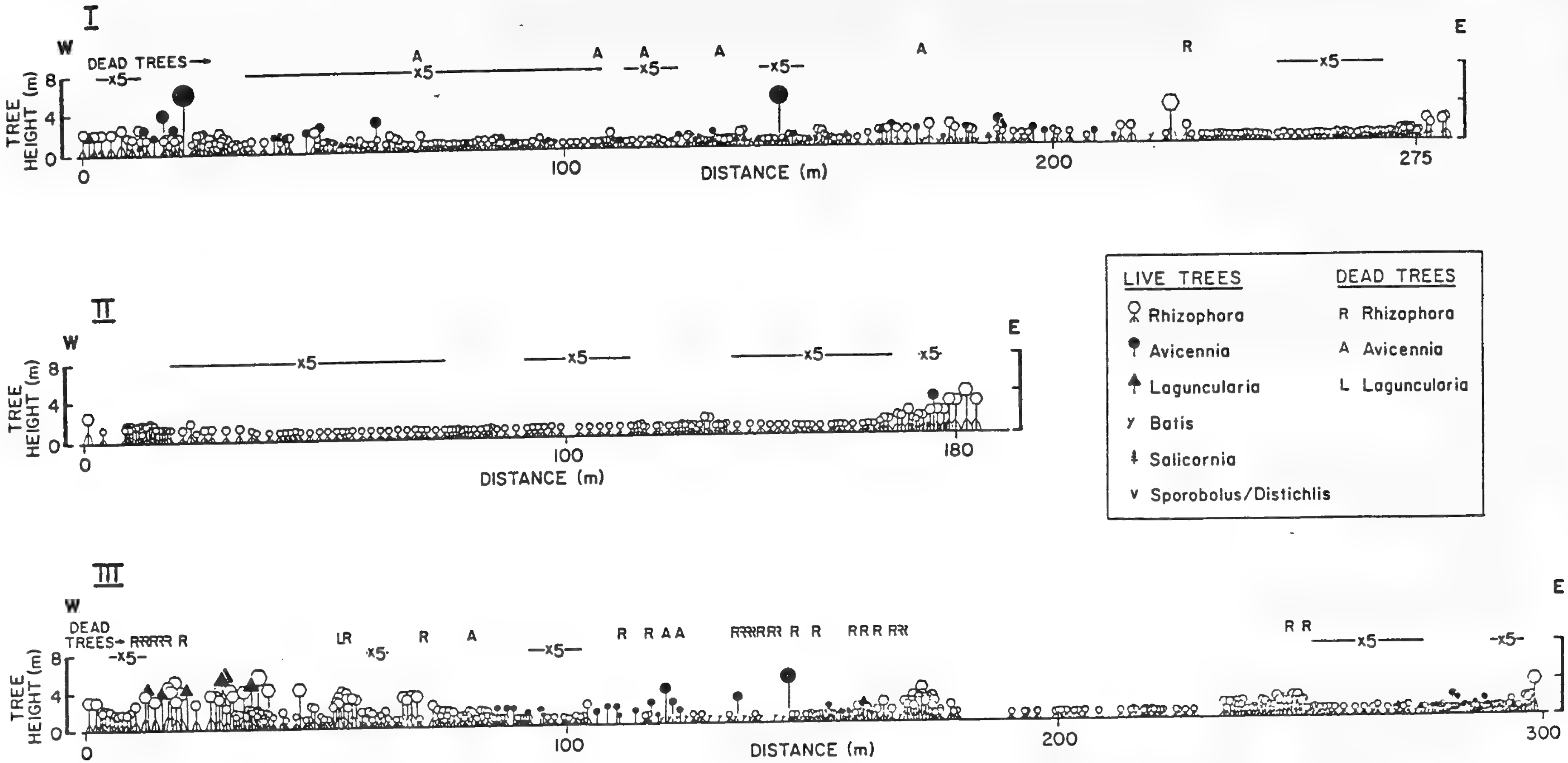

Fig. 6: Transects I-III, Twin Cays (x5 indicates that the density of Rhizophora was five times that shown on the transect).

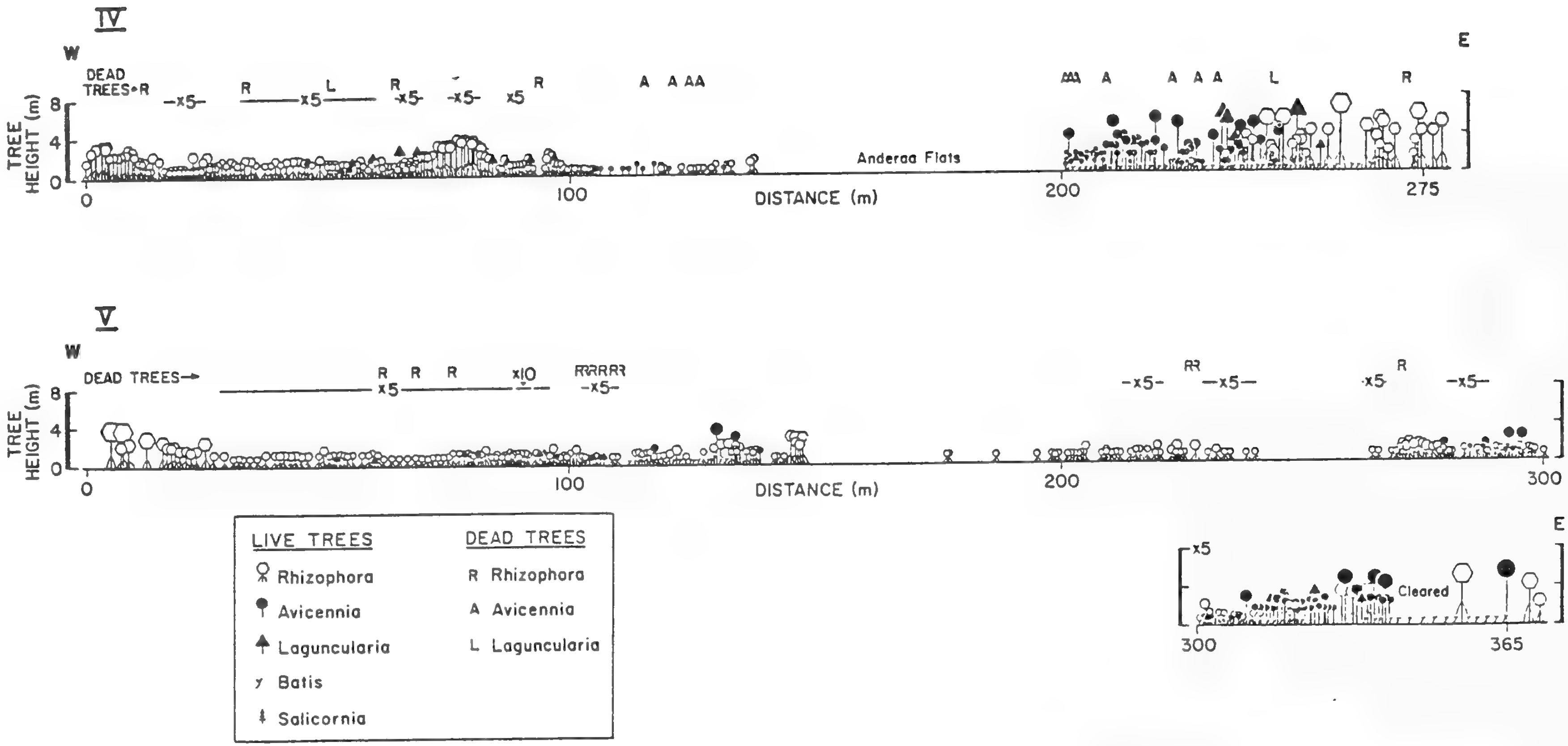

Fig. 7: Transects IV and V, Twin Cays (x5 indicates that the density of Rhizophora was five times that shown on the transect).

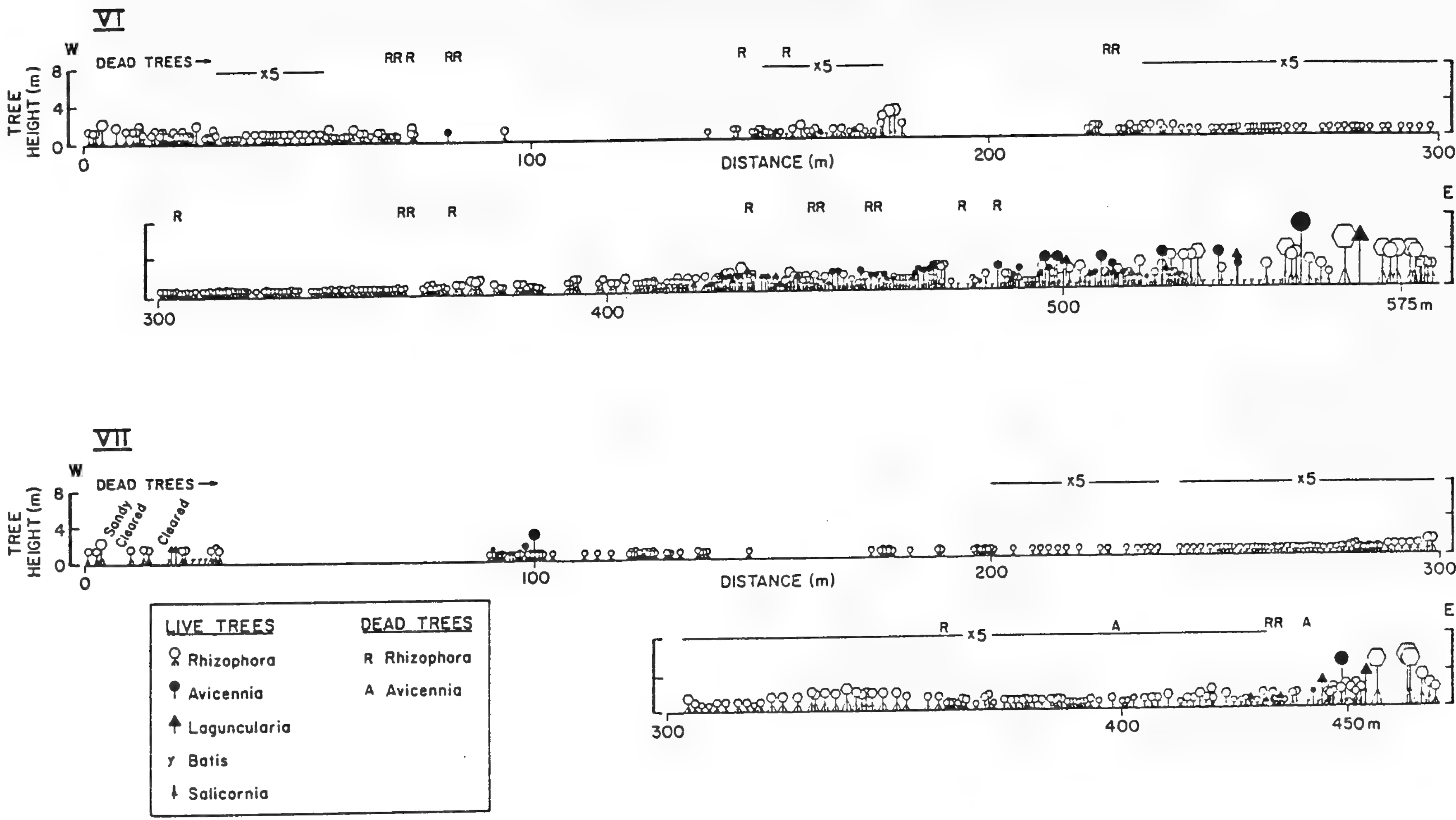

Fig. 8: Transects VI and VII, Twin Cays (x5 indicates that the density of Rhizophora was five times that shown on the transect).

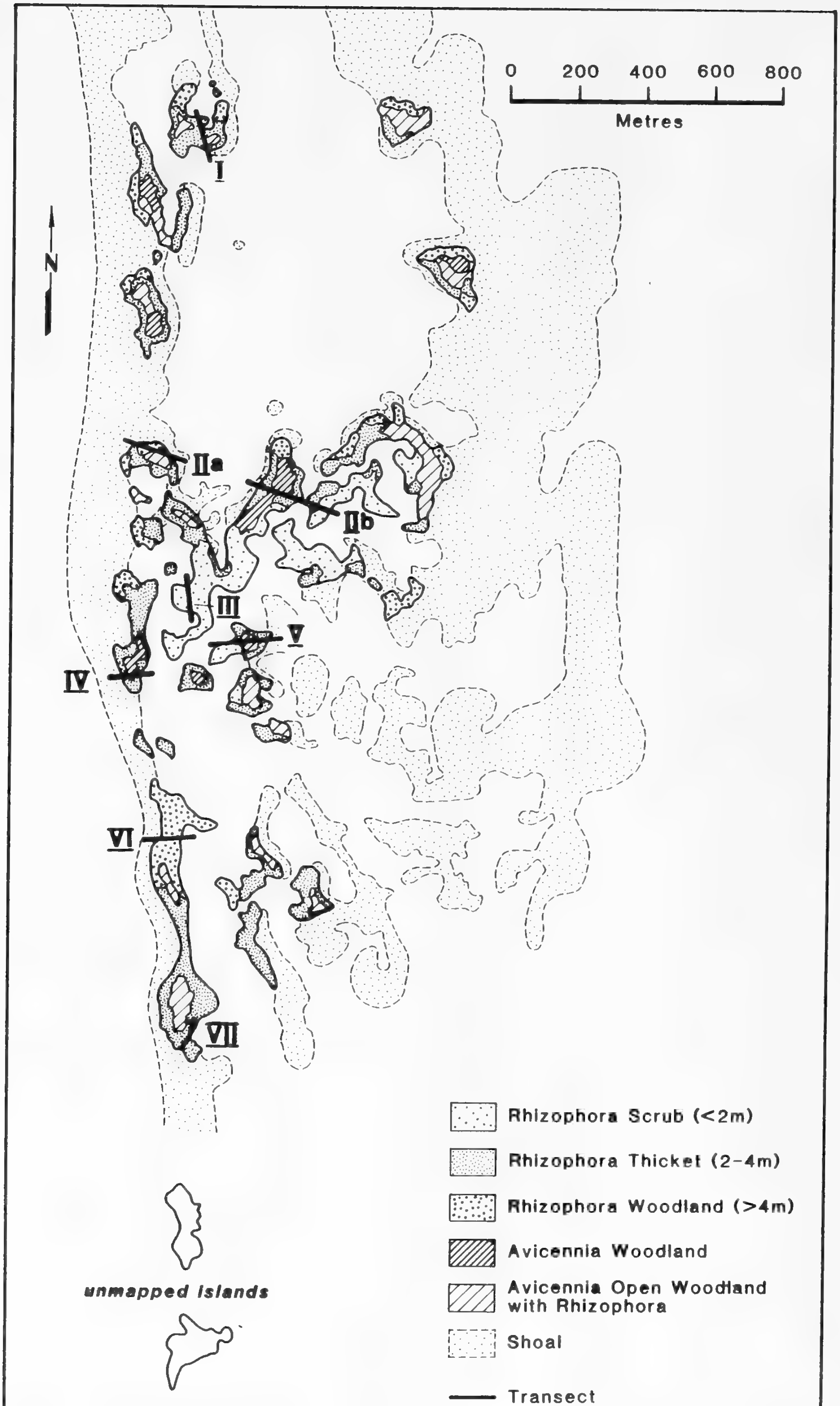

Fig. 9: Vegetation map of Blue Ground Range.

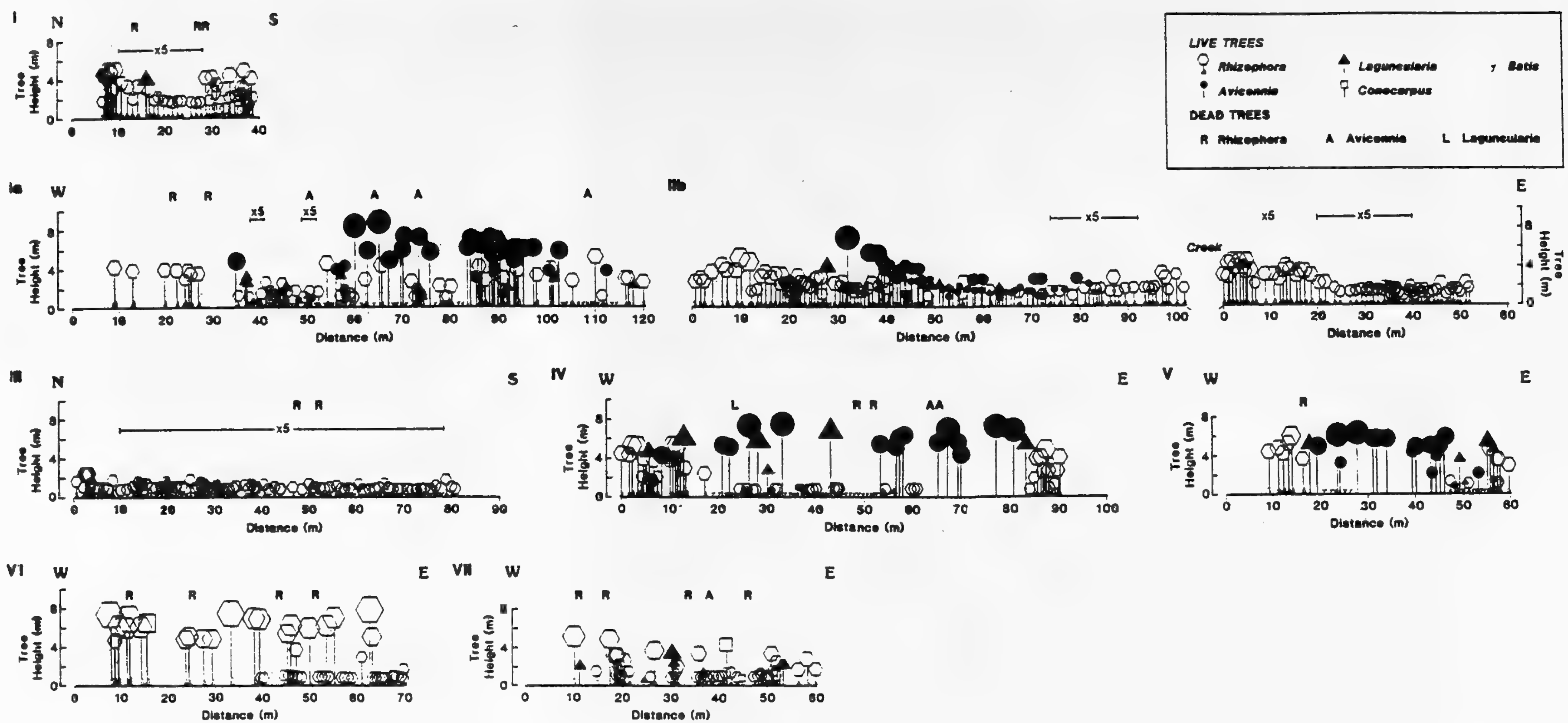

Fig. 10: Transects I-VII, Blue Ground Range (x5 indicates that the density of <u>Rhizophora</u> was five times that shown on the transect).

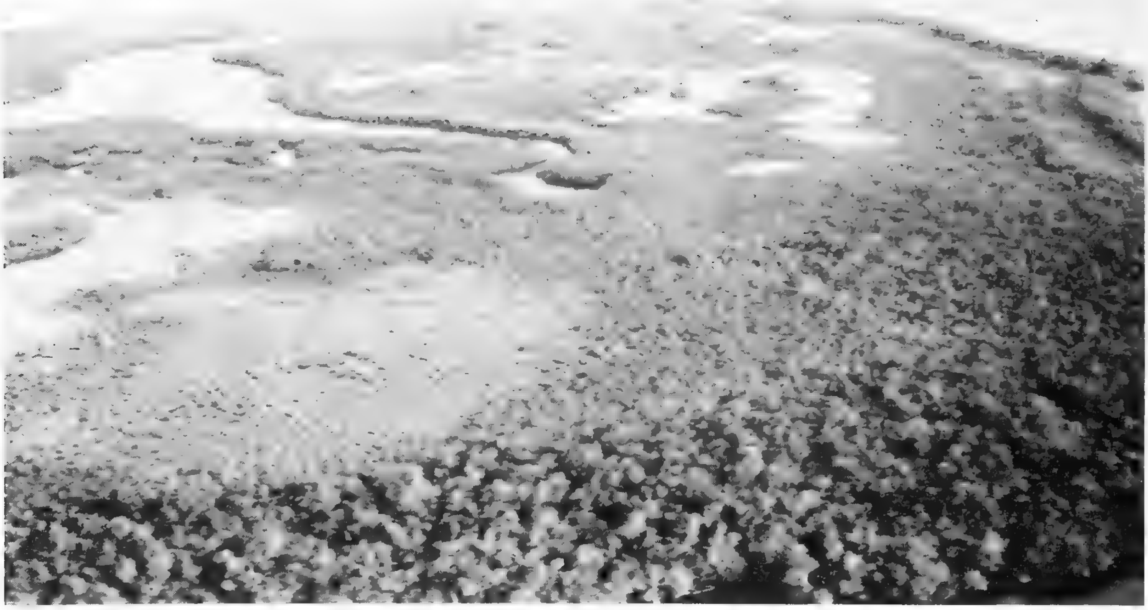

Plate 1: Oblique aerial photograph looking north along the eastern island of Twin Cays. Standing water can be seen over the unvegetated flats of the interior. There is an area of Rhizophora scrub in the left foreground. The area marked as cleared on the map (Fig. 5), presumably devastated by Hurricane Hattie, can be seen on the upper right of the photograph.

Plate 2: Inside Rhizophora woodland, Twin Cays.

Plate 3: Rhizophora thicket fringing a major creek (or bogue) through Twin Cays.

Plate 4: Rhizophora scrub within the interior of the western island, Twin Cays.

Plate 5: Inside Avicennia woodland, northern Twin Cays.

Plate 6: Avicennia open woodland with Rhizophora, Twin Cays.

Plate 7: Unvegetated flat on southern end of Tobacco Range, showing extensive dead trees, presumably killed during Hurricane Hattie, 1961.

Plate 8: Avicennia open woodland with Rhizophora, with a carpet of Batis, Twin Cays, showing numerous dead Rhizophora trees.

Plate 9: Small meandering creek, fringed by Rhizophora thicket, Twin Cays.

Plate 10: Individual Rhizophora within Rhizophora scrub, Twin Cays, showing that the scrub is composed of mature individuals, and is not always composed of Rhizophora seedlings.

ATOLL RESEARCH BULLETIN

NO. 428

THE TOBACCO RANGE FRACTURE ZONE: A UNIQUE SYSTEM OF SLUMPED MAGROVE PEAT

BY

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THE TOBACCO RANGE FRACTURE ZONE, BELIZE, C.A.:

A UNIQUE SYSTEM OF SLUMPED MANGROVE PEAT

BY

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ABSTRACT

During February 1986, a 0.5 km-wide by 2.0 km-long region of spectacular bottom topography was discovered off the west coast of the northernmost island of the Tobacco Range mangrove group, Belize. This unusual marine landscape consisted of vertical submarine peat exposures, tilted slumping blocks of fossil peat, and long narrow fractures. The upper edges of the exposed vertical walls were composed of a 10 to 20 cm-thick veneer of a living *Thalassia testudinum* community atop a 1 to 7 m-thick consolidated layer of fossil mangrove peat. This seagrass-dominated peat surface sloped westward to its point of lowest relief (<1.0 m, 500 m offshore) and contained poorly sorted sandy gravels and gravelly carbonate sands (mostly mollusc and foraminiferan fragments) on the unfractured surfaces and muddy calcareous peat sediments within the fracture depressions. The widths of the fractures varied from narrow fissures (< 0.1 m-wide) to upwards of 30 m across. Fractures nearest the island tended to be at right angles to the shoreline, dendritic or digital, and less weathered than those farther seaward. Fractures toward the northeast and southwest ends of the system retained vertical or undercut walls up to 7-m thick along their entire perimeters, whereas central fractures tended to have collapsed outer walls. Most of the slumped blocks contained sparse *T. testudinum* beds

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identifying their upper surfaces and had been tilted at chaotic angles ranging from horizontal to 35°. Multiple levels, platforms, and undercuts are conspicuous along most of the vertical walls revealing the preservation of a bedded zonational pattern in the peat. The majority of the peat is coarse-fibered material of mangrove origin, with partially decomposed fine-fibered deposits in the lower strata.

The Tobacco Range fracture zone has provided some unusual habitats for marine organisms. In general, the overall biota was sparse, consisting of the typical members of the *T. testudinum* community plus certain unique elements. The unusual elements appear to be in response to (1) new spatial heterogeneity adding increased surface area and shelter, (2) diverse sedimentary substrates utilized by psammobiotic forms, and (3) a trapping effect that concentrates large mobile gastropods. This last phenomenon has resulted in "interior halos", since the physical bioturbation by these large animals apparently has eliminated rooted plant life and other sessile organisms along the perimeters of the sedimentary depressions at the bases of the vertical peat walls.

The peat slurry between the slumped blocks of coarse-fibered peat at the innermost limits of slumping, the undercut peat exposures at the lowest depositional levels, the decomposed sections of fine-fibered peat found in cores adjacent to slumping, the presence of escaping stained humic waters, and the interconnected dendritic slump patterns all suggest that fracturing and slumping may be related to aerobic decomposition and erosion following hydrostatic intrusion of the underlying fine-fibered peat. The subdued relief of the peat blocks in the broad depressions at the outer limits of slumping indicates that collapsing of submerged peat has been taking place for centuries and possibly millennia. The isolated fracture areas eventually become interconnected by additional dendritic branches, which continue to slump to form broader slump depressions.

INTRODUCTION

On 18 February 1986, the research-team took advantage of unusually calm waters to explore bottom habitats to the north of the Smithsonian Institution's field station on Carrie Bow Cay (Fig. 1). We cruised an inflatable boat at 10 knots while observing the bottom topography to depths of 5-10 m. However, we were unprepared for the sharp 3-dimensional fractured relief that suddenly appeared in the otherwise monotonous beds of *Thalassia testudinum* König at the Tobacco Range mangrove group (Fig. 1). The following day an aerial survey was flown with oblique photography (e.g., see Frontispiece, this volume) used to document the overall Tobacco Range geomorphology and the extent of the fractures. These photographs were compiled to produce the map in Figure 2, which revealed a tendency toward a digital pattern of slumping with longer and narrower depressions extending shoreward, but not quite reaching the intertidal zone. There were also several isolat-

ed slump depressions near the coastline (Figs. 2 and 3). Reconnaissance by snorkling revealed an extensive 2.0 km-long by 0.5 km-wide region of spectacular bottom topography comprised of vertical submarine peat exposures, tilted slumping blocks of fossil peat, and long narrow fractures extending along the north coast of the northernmost island. Herein we provide an overview description and photographs of this unusual marine landscape which has stimulated more detailed biological and geological studies.

Geomorphology

Adjacent to the shoreline, the peat was pockmarked with small eroded depressions (up to 20 cm wide) caused by wave action and the predominant cover was the ruffled form of *Lobophora variegata* (Lamouroux) Womersley (see Littler *et al.* 1989, page 114). This approximately 10-m wide shallow zone graded into a *Thalassia testudinum* community that continued to the lagoon floor beyond the fracture zone. The peat between the shoreline and the fracture zone had numerous 1-m deep depressions (up to 5-m wide), gouged by trapped logs and debris, containing carbonate and peat sediments (see Fig. 13 of Macintyre *et al.*, 1995 this volume). Relatively few of the fractured peat blocks or walls showed evidence of erosion by water movement in their shoreward perimeters (Fig. 4), i.e., most have flat walls and angular corners. The upper edges of the exposed vertical walls were composed of a 10 to 20 cm-thick veneer of a living *Thalassia testudinum* community (Fig. 5) atop a 1 to 7m-thick consolidated layer of fossil mangrove peat. This seagrass dominated peat surface sloped westward to its thinnest point (< 1.0 m, 0.3 to 0.5 km offshore) and contained scattered pockets of poorly sorted organic debris and skeletal carbonate sediments. It is this gradually sloping peat seafloor that has been broken up to form the unique bottom topography of the area.

The widths of the fractures generally varied from <0.1 m-wide fissures (Fig. 6) to basins of 30 m across (Fig. 2). The fractures consisted of vertical walls, occasionally undercut, that dropped from the shallow 1-4 m level of the *Thalassia testudinum* bed to a depth of 2-10 m (Fig. 7). Fracture walls near the island (southeastward) tended to be at right angles to the shoreline, digital or dendritic, and less weathered (younger) than those farthest seaward. The majority of new cracks (Fig. 6) occurred on the shoreward margin of the fracture zone. Toward the northwest, several of the weathered central fractures graded deeper into smooth rounded peat hummocks on a *T. testudinum*-covered muddy-sand lagoonal bottom at about 300-500 m offshore (Fig. 2), implying that the central seaward portion of the system began fracturing earlier. Interestingly, fractures toward the northeast and particularly toward the southwest ends of the system (Fig. 2) tended to retain vertical or undercut walls along their entire perimeters.

Within the fractures, on the bottom or partially sunken into soft mud sediments, are large slumped fragments of the consolidated mangrove peat, most of which are angular and block-like in shape (Fig. 8). These blocks are in various stages of splitting off from the *Thalassia testudinum* flats at the edges, followed by vertical to tilted slumping and sinking into the slurry of partially decomposed peat muds at the bottom of the fractures (Fig. 9). This process is ongoing, as documented by the photograph of one large block falling away from the perimeter of a fracture (Fig. 10). Most of the slumped blocks still contain sparse *T. testudinum* beds that identify their upper surfaces, which have been tilted at angles ranging from horizontal to 35° (Fig. 11A). Some of the blocks that have sunken into the fracture depressions exhibit the classical backward tilting associated with slump features (Fig. 11B, Thornbury, 1954); however, other blocks form a chaotic jumble (Fig. 12) with no consistent orientation. Multiple levels, platforms, and undercuts are apparent along most of the vertical edges of the peat deposits revealing the preservation of a bedded structure in the peat (Figs. 13 and 14). This presents a stratified pattern of beds particularly evident on the more freshly fractured surfaces. Stained humic waters often escape from the interface between the bottom sediments and the basal strata of fine-fibered peat, greatly diminishing water clarity, and implicating deep hydrostatic flows. Most of the peat consists of preserved coarse-fibered material of mangrove origin with a well-developed *Thalassia* root system in the upper sections. There are occasional intact mangrove tree trunks and root systems within the upper strata, mostly <2 m deep, that show excellent preservation.

Sedimentology

During March 1987, a series of surface-sediment samples were collected at ~ 60 m intervals from two 300 m-long transects across the central region of the fracture zone. These transects, one extending from the northwestern end of the core study transect (Macintyre et al., 1995, this volume) and the other 100 m to the southwest, began in the near-shore unfractured peat and extended across both relatively fresh and older slump areas, to the level *Thalassia*-covered lagoonal bottom west of the fracture zone.

The sediment samples were treated with 5% sodium hypochlorite to remove dissolvable organic matter and separated into three basic size fractions by wet sieving: gravel (>2 mm), sand (2 mm to 63 μm), and silt (63 μm to 4 μm), whereas clays (<4 μm) were separated by settling and decantation. The textual classification of Folk (1961), relating the percentage gravel to the ratio of sand to mud (including both the silt and clay fractions), was used to describe the samples (Fig. 15) recognizing the inherent difficulty of carrying out size analyses on sediments that

include a mixture of both carbonate grains and peat debris. In addition, the sand and gravel fractions were studied microscopically to determine the origins of the major constituents (Fig. 15).

The gravel and sand-sized carbonate fractions did not vary substantially between the two transects. Molluscs and benthic foraminifera (predominantly peneroplids) were the dominant contributors with varying minor amounts of *Halimeda* segments and echinoid fragments. The better sorted sandy gravels and gravelly carbonate sands of the unfractured peat surfaces gave way to muddy calcareous peat sediments in the fractured and slumped areas (Fig. 15), which included more calcareous components with increasing distance from shore (visible in Frontispiece, this volume). Finally, somewhat muddy, gravelly carbonate sediments (with only traces of peat) occurred in the 6 m-deep *Thalassia* beds beyond the fracture zone.

Biology

Observations of the general biota were made from maneuverable tow boards (Tsuda and Abbott, 1985) along transects on 20-21 February 1986. The biota within the fractures was sparse and, with few exceptions, relatively uniform from fracture to fracture. The plant communities and composition are detailed in Littler et al. (1995, this volume) and were dominated by the *Thalassia testudinum* community on the upper surfaces of both slumped and unslumped peat. The brown alga *Lobophora variegata* was abundant on the vertical walls (Fig. 16) along with patches of the green algae *Caulerpa* spp., *Anadyomene stellata* (Wulfen) C. Agardh, and the seagrass *Halophila decipiens* Ostenfeld. The soft mud and sand bottoms of fractures were dominated by patchily distributed populations of siphonaceous algae having root-like rhizoidal systems [e.g., rhizophytes such as *Halimeda incrassata* (Ellis) Lamouroux, *Halimeda monile* (Ellis & Solander) Lamouroux, *Udotea cyathiformis* Decaisne, *Penicillus capitatus* Lamarck, and *Rhipocephalus phoenix* (Ellis & Solander) Kützing (Fig. 17) along with patches of the seagrass *Halophila decipiens* (Fig. 18)]. Abundant drift blades of *T. testudinum* contributed massive quantities of organic debris to the system (Fig. 19).

The most conspicuous sessile animal species were two sponges, the yellow semi-encrusting form *Mycale laevis* (Carter) (Fig. 20) reaching sizes exceeding 0.25 m^2 and the burgundy vasiform species *Mycale laxissima* Duch. & Mich. (Fig. 21) reaching 0.1 m^2 in diameter. Also common were the pink sponge *Monanchora unguifera* (Laubenfels), the white sponge *Leucosolenia* sp., and the black ball sponge *Ircinia felix* (Duch. & Mich.). On the fracture walls, the large black tunicate *Ascidia nigra* (Savigny) was also conspicuous, while colonies of the orange tunicate *Ecteinascidia turbinata* Herdman (Fig. 22) were common but otherwise rare on nearby mangrove

systems (i.e., north of the Blue Ground Range, Fig. 1). The giant anemone *Condylactis gigantea* (Weinland) was frequent on sunken peat blocks.

Of the mobile fauna, the jellyfish *Casiopea xamachana* Bigelow was abundant on the muddy sedimentary surfaces (Fig. 23). Nurse sharks (*Ginglymostoma cirratum* Bonnaterre) were common and the southern stingray (*Dasyatis americana* Hildenbrand and Schroeder) was frequently observed buried in the soft sediments (Fig. 24A) where it caused considerable bioturbation (Fig. 24B).

One of the fascinating features of the fracture zone was that large mobile gastropods had fallen into the fractures and become trapped because they could not ascend the vertical peat walls (Fig. 25A). These included three species of large helmet shells, *Cassis tuberosa* L., *Cassis flammea* L., and *Cassis madagascariensis* Clench as well as the queen conch *Strombus gigas* L. and the milk conch *Strombus costatus* Gmelin. These large gastropods apparently traversed the bottom sediments until encountering a vertical wall which they then paralleled until presumably starving to death (Fig. 25B). In 1986, there were dozens of examples, mostly dead but some living, each at the end of its grooved trail. This phenomenon has resulted in what we have termed "interior halos", since the physical bioturbation by these large animals apparently eliminated rooted plant life and other sessile organisms (Fig. 25A & B) along the perimeters of the depressions at the bases of the peat walls.

The spatial heterogeneity created by the slumped peat blocks (e.g., crevices, undercut ledges, Figs. 8, 11, 12, and 14) provided refuge habitats for various fishes and crustaceans that were not present in normal seagrass beds. Fishes responding to the rugosity with augmented populations were cuberra snapper (*Lutjanus cyanopterus* Cuvier and Valenciennes), grey snapper (*Lutjanus griseus* Linnaeus), yellowtail snapper (*Ocyurus chrysurus* Bloch), blue striped grunt (*Haemulon sciurus* Shaw), blue tang (*Acanthurus coeruleus* Bloch and Schneider), blue head wrasse (*Thalassoma bifasciatum* Bloch), and stoplight parrotfish (*Sparisoma viride* Bonnaterre). Other fishes utilizing the sunken topographic relief of the fractures in numbers exceeding those of the surrounding seagrass beds were yellow goatfish (*Mulloides martinicus* Cuvier and Valenciennes) and, as mentioned, southern stingrays and nurse sharks.

The Caribbean spiny lobster *Panulirus argus* (Latreille) was common in peat crevices of the southwestern fractures, while the Caribbean king crab *Mithrax spinosissimus* was common on vertical faces in the shoreward shallow portions of the fractures.

Heart urchins [*Meoma ventricosa* (Lam.)] were abundant along with the crown conch *Melongena melongena* L. in the fractures (particularly the more-westward

predominantly carbonate-rich sediments). Uniquely, the sea urchin *Astropyga magnifica* Clark (Fig. 26), which occurs typically only in very deep oceanic waters, was present in two of the southwesternmost fractures, representing the only known collection record for this species from Belize (D. Pawson, personal communication, 1995). The long-spined sea urchin *Diadema antillarum* Philippi (Fig. 27) was also common.

DISCUSSION

We have observed submerged peat exposed on the seafloor margins and interior channels of most mangrove islands and there are particularly good examples to the southwest at nearby Twin Cays. However, to our knowledge there are no reported sites of fracturing and slumping, comparable to that occurring at Tobacco Range, in the Central Barrier Reef Province of Belize. There is, however, one area adjacent to the mangrove shoreline north of Crickozeen Creek, on the west coast of the Tunneffe Islands, Northern Belize Barrier Reef Province, where similar fracturing and slumping may have occurred (Stoddart, 1963). This crescent-shaped slump area was about 10 m wide and approximately 200 m long with "subsidiary smaller cracks both to the south and seaward". Unfortunately, the area was not studied in detail, so that it is not known whether the slumping is associated with peat deposits. Stoddart suggested that this slumping was caused by "extreme wave conditions" (p. 87) that occurred during the impact of Hurricane Haiti, which had just passed over the area four months prior to his observations.

The relatively larger slump depressions toward the center of the array off Tobacco Range (Figs. 2 and 3) are more collapsed and weathered at their outer seaward margins suggesting that this region of the system fractured earlier than some of the more active shoreward (eastward), northern, and southern portions.

The Tobacco Range fracture zone has provided some atypical habitats for marine organisms. In general, the overall biota was sparse, consisting of the constituents of the typical *Thalassia* community plus certain unusual or even unique elements. The unusual elements seem to be in response to: (1) new spatial heterogeneity adding shelter and increased surface area, (2) soft substrates utilized by sediment dwellers, and (3) a trapping effect that concentrates large mobile gastropods creating "interior halos".

The overriding questions concerning the Tobacco Range fracture zone are: What initiated the fracturing and slumping?; How long has this process occurred?; and What controls the pattern of slumping? Considering the possible causes, the five most realistic hypotheses are:

(1) Subsurface aerobic decomposition of fossil peat in the presence of oxygenated ground waters.

(2) Hydrostatically-induced subsurface erosion, possibly tidal/lagoonal driven, to form voids that collapse.

(3) Shock to the sedimentary sea floor caused by severe wave conditions associated with hurricanes (Stoddart, 1963).

(4) Liquefaction of deep mud layers by seismic events such as blasting during oil exploration (Fig. 28) or earthquakes.

(5) Dendritic relief patterns in the underlying Pleistocene limestone.

The slurry of muddy peat between the fallen blocks of peat at the inner limits of slumping, the undercut peat exposures, the partially decomposed sections of fine-fibered peat found in cores adjacent to slumping (Macintyre et al., 1995, this volume), the presence of escaping stained humic waters, and the dendritic slump patterns all suggest that fracturing and slumping are related to the decompositional erosion of older fine-fibered peat. This removal of the underlying fine-fibered peat probably involves processes of oxidation, gravity flow, and bottom current erosion (Hypotheses 1 and 2), which could be driven by hydrostatic forces related to the passage in the barrier reef 2 km directly eastward of Tobacco Range and to the atoll-like lagoon of Tobacco Range. These processes appear to concentrate initially along narrow fronts resulting in a poorly developed dendritic pattern (Figs. 2 and 3). In some cases, the older fine-fibered peat is removed some distance shoreward of the exposed peat walls, which results in isolated slump areas.

Stoddart's (1963) observations on the atoll-like Turniffe mangrove system following the impact of Hurricane Hattie suggest the hypothesis (No. 3) that catastrophic hydrostatic forces could be responsible for initiating the fracturing and slumping in the Tobacco Range system where the consolidated coarse-fibered peat deposits are underlain by thick deposits of easily erodable fine-fibered layers and thin slippery basal muds.

Hypothesis 4 is not likely, although seismic blasting tracks are clearly visible adjacent to the northeastern portion of the fracture zone (see Fig. 28). Blasting from petroleum exploration ships has occurred next to the peat beds of many of the Belizean mangrove islands, such as nearby Twin Cays (Fig. 1), and no comparable slumping has occurred. Also, the weathered seaward central slump depressions greatly predate seismic testing. It should be kept in mind, however, that natural

seismic events (earthquakes) have occurred and continue to be reported in this area and may have played a role in the initiation of slumping processes off Tobacco Range.

It is conceivable that dendritic relief on the underlying Pleistocene limestone surface, possibly old spur and groove deposits (Hypothesis 5), might have had some control of these slump patterns. This, however, could only be confirmed by detailed seismic studies.

It is not possible to determine how or when the fracturing and slumping started in this area. The very subdued relief of the peat blocks in the broad depressions at the outer limits of slumping (Fig. 29), and the complete colonization by the slow growing seagrass, *Thalassia testudinum*, indicates that collapsing of submerged peat has been occurring for a long period of time -- centuries or possibly millennia. We do know that the process is ongoing since we have noted the formation of new cracks and fissures (Fig. 6) and observed slumping (Fig. 10) during the present study. The isolated slump areas eventually connect to the main areas, forming additional branches of the dendritic pattern. With time, most of the peat deposits between the dendritic branches will collapse forming broader slump depressions.

ACKNOWLEDGEMENTS

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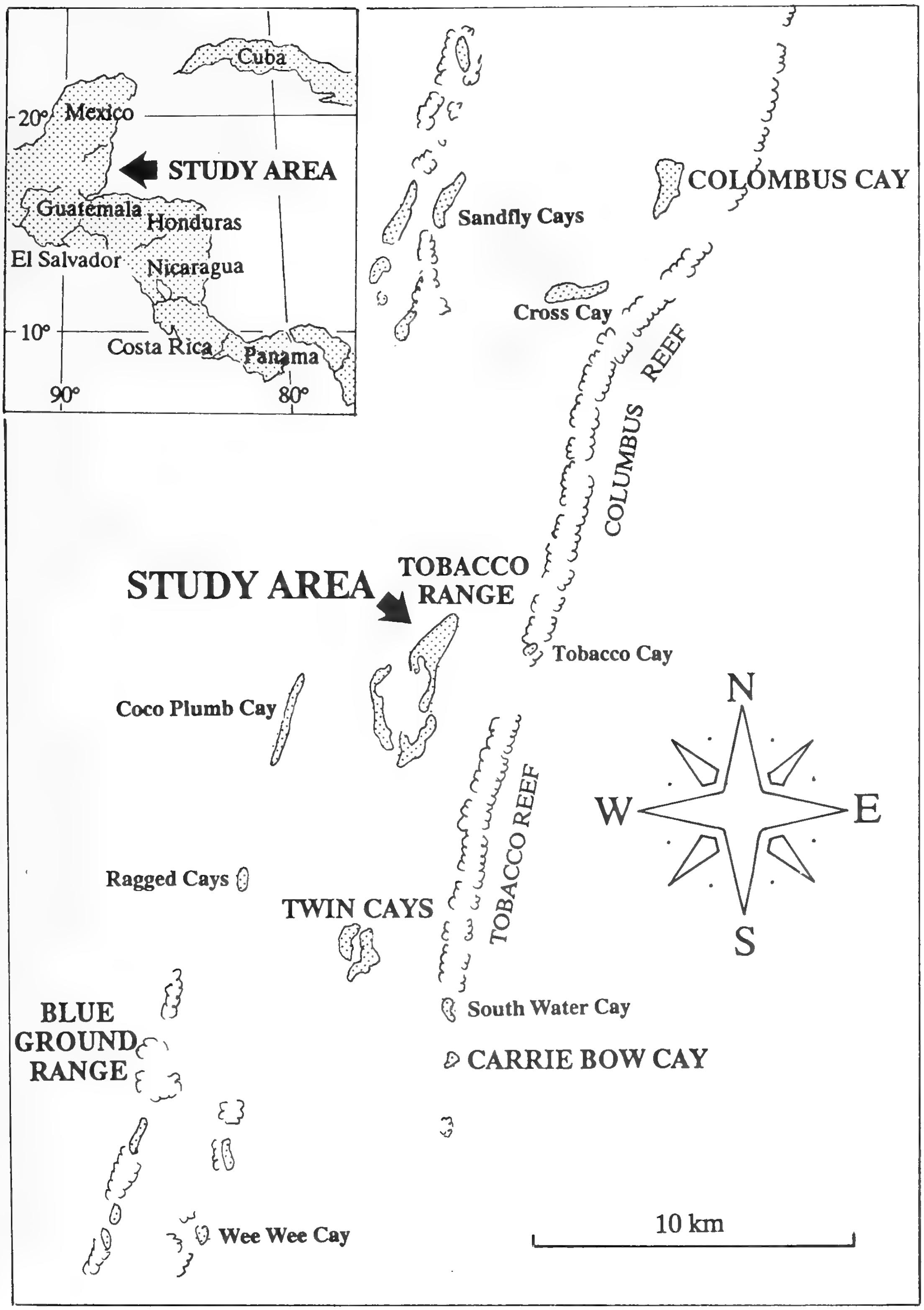


Figure 1. Map of Central Province of the Belize Barrier Reef showing location of Tobacco Range mangrove system and study area.

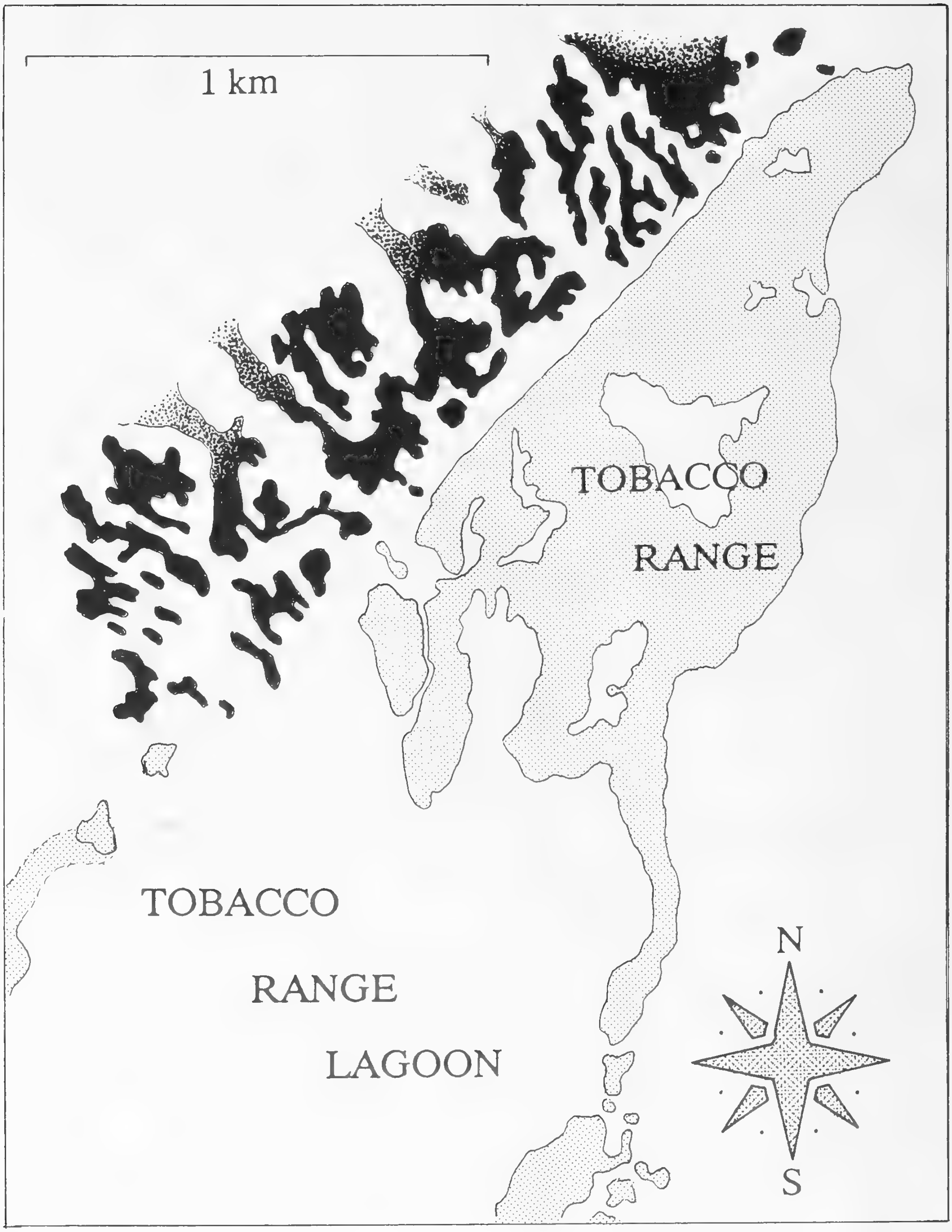


Figure 2. Detailed map showing the Tobacco Range Fracture Zone off the northeastern island (black shading, based on aerial photography).

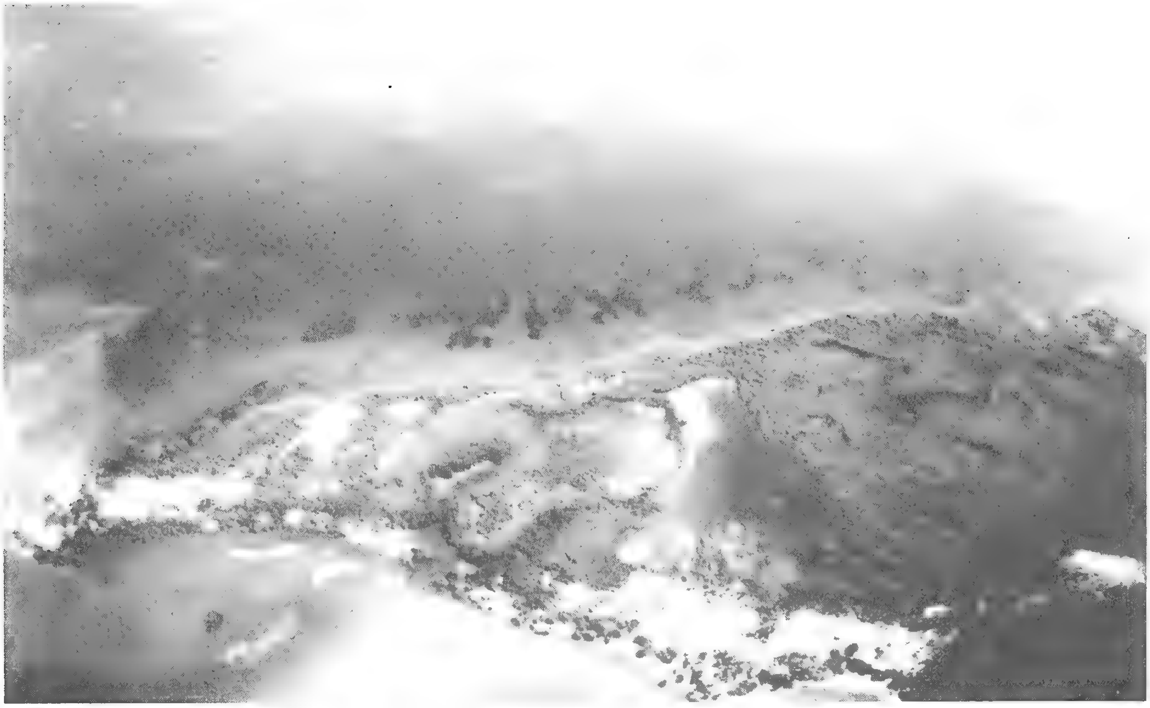


Figure 3. Oblique aerial photograph, looking northward at the northeastern island of Tobacco Range, showing the dendritic slump areas (dark) of the fracture zone.

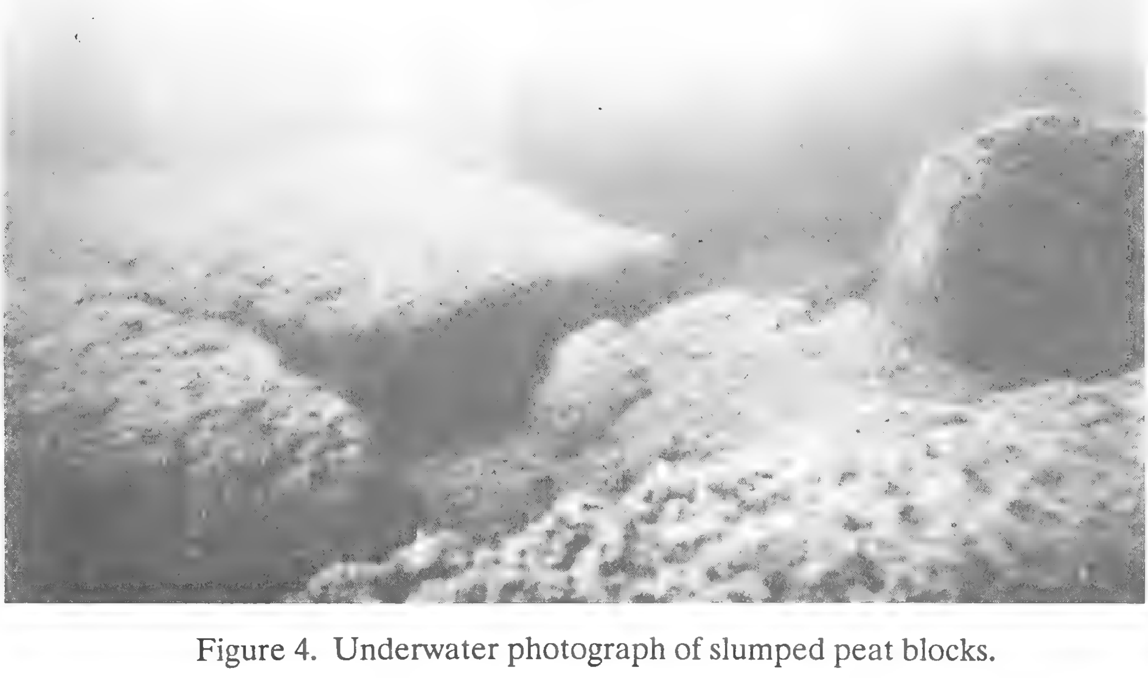


Figure 4. Underwater photograph of slumped peat blocks.

Figure 5. *Thalassia testudinum* - dominated community in nearshore unfractured area.

Figure 6. Initial crack prior to incipient fracturing and slumping.

Figure 7. Exposed wall of fossilized peat on fracture margin.

Figure 8. Array of slumped peat blocks.

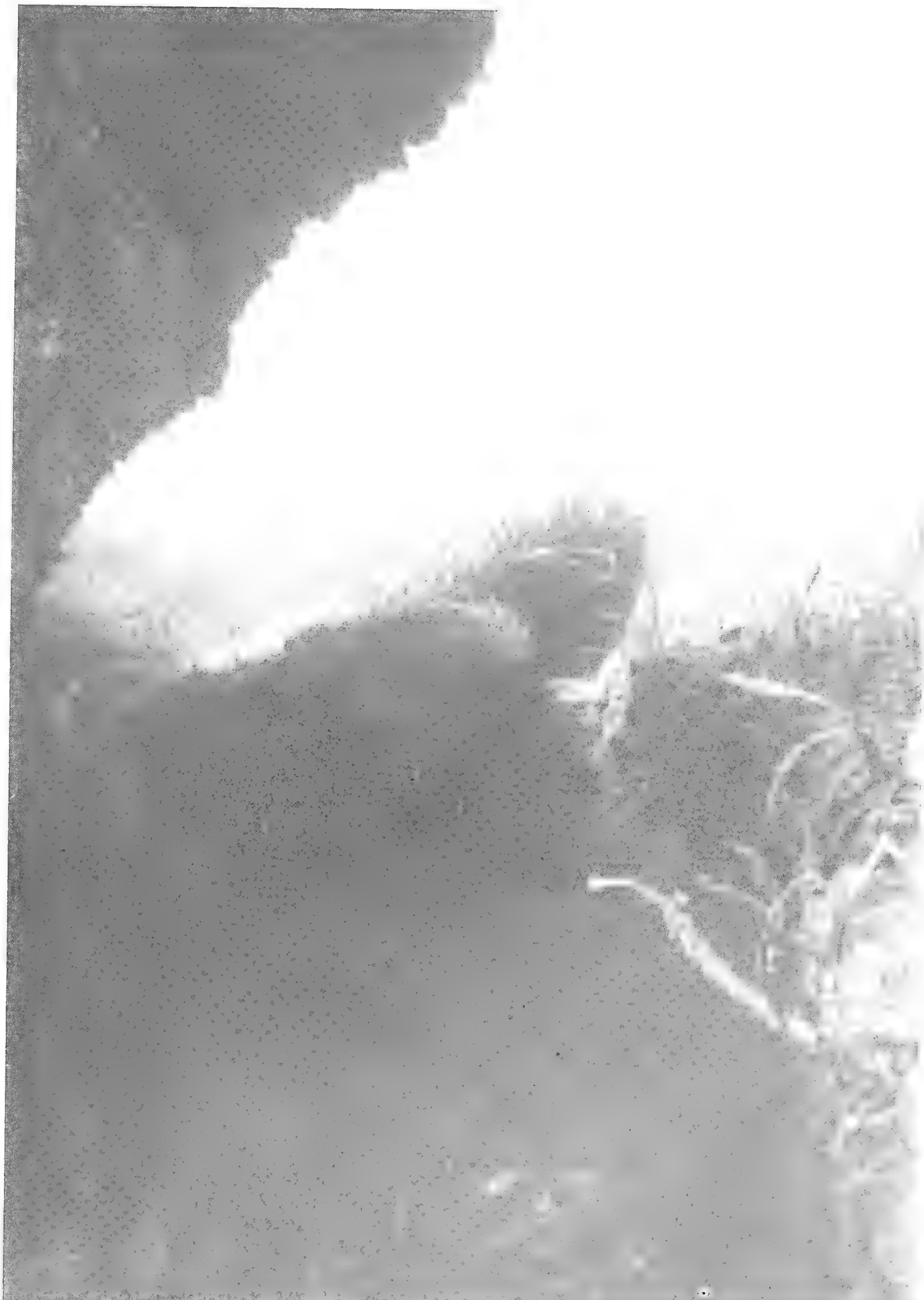


Figure 9. Peat block partially sunken into slurry of peat mud.

Figure 10. Peat fragment in the process of slumping.

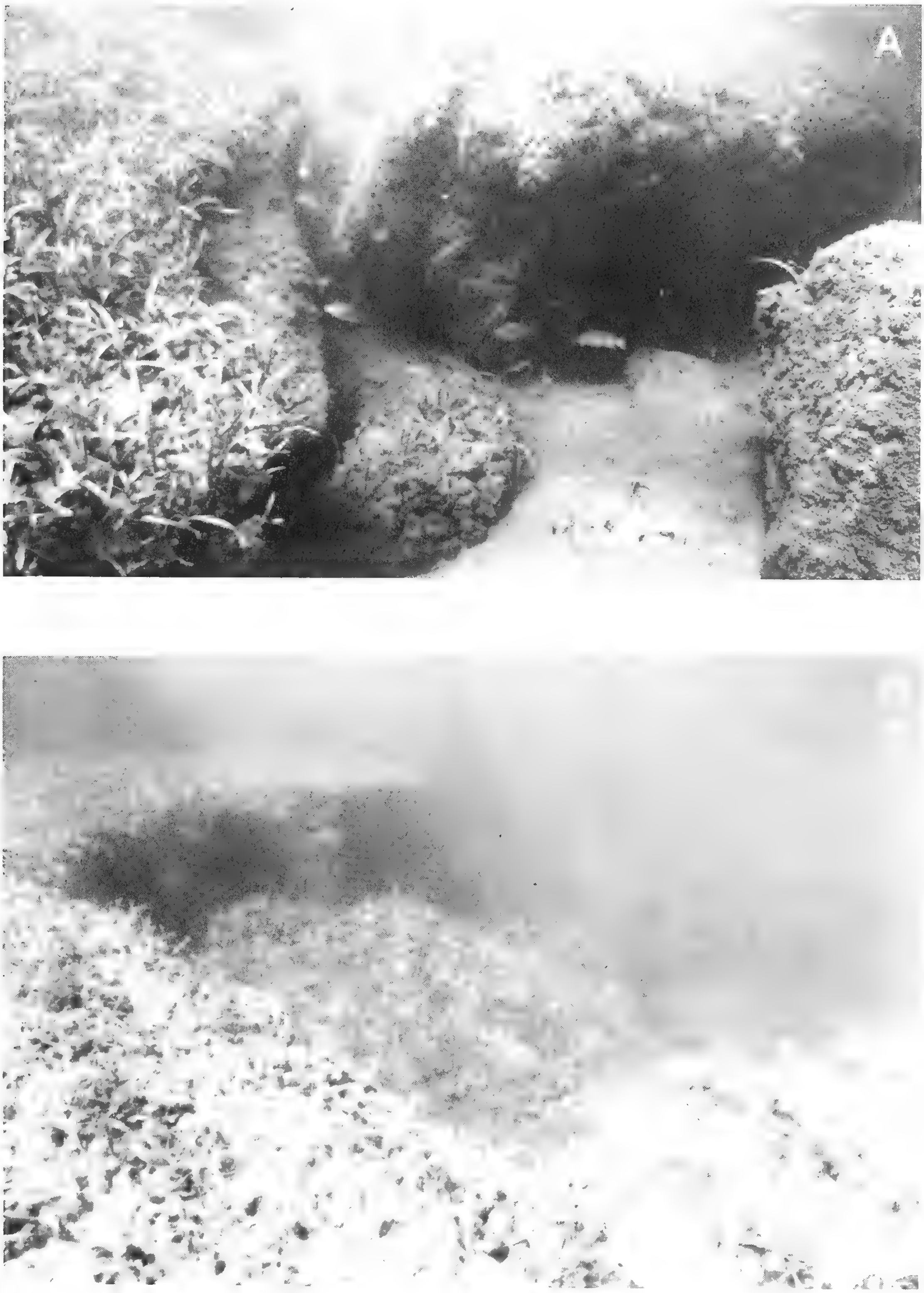


Figure 11 A & B. Tilted peat blocks showing sparse *Thalassia testudinum* community on upper surfaces.

Figure 12. Chaotic jumble of peat blocks.

Figure 13. Stratified pattern of depositional zonation.

Figure 14. Platform and undercut features of peat deposits.

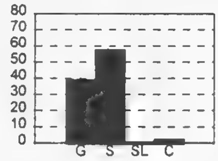
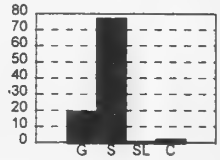
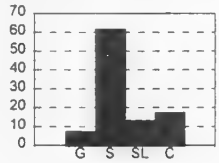
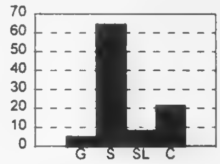
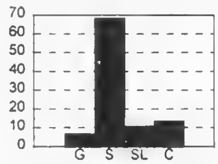
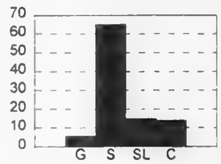
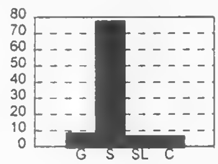
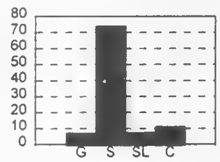
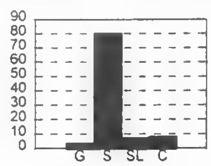
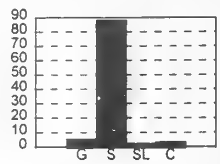
Seafloor Characteristics	Transect that follows and extends core study transect (Fig. 2, Macintyre et al., 1995, this volume)	Parallel transect 100m southwest of core study transect
Shallow unfractured peat surface adjacent to shoreline. Depth 3m	Poorly sorted sandy gravel. Dominantly molluscs with some benthic foraminifera, Halimeda and echinoids. 	Poorly sorted gravelly sand. Molluscs , benthic foraminifera and Halimeda. Some echinoid and peat fragments. 
Sediment from between the most recently collapsed peat blocks at inner limit of slumping. Depth 6m	Very poorly sorted gravelly muddy sand. Mostly peat. Scattered grains of molluscs, benthic foraminifera, echinoids and Halimeda. 	Very poorly sorted gravelly muddy sand. Mostly peat. Traces of Halimeda, molluscs, and benthic foraminifera. 
Area of low relief slumping located seaward of active slumping sites. Depth 6m	Very poorly sorted gravelly muddy sand. Mollucs, benthic foraminifera and peat. Some echinoids and Halimeda. 	Very poorly sorted gravelly muddy sand. Peat with molluscs, benthic foraminifera, and some echinoids. 
	Very poorly sorted gravelly muddy sand. Molluscs and Halimeda. Some peat, benthic foraminifera, and echinoids. 	Very poorly sorted gravelly muddy sand. Molluscs, benthic foraminifera, Halimeda and echinoids. Abundant peat. 
Thalassia covered seafloor beyond fracture and slump zone. About 300m from shore. Depth 6m	Very poorly sorted,slightly gravelly muddy sand. Molluscs and benthic foraminifera with some Halimeda, echinoids and peat. 	Very poorly sorted gravelly sand. Molluscs and benthic foraminifera with some Halimeda, echinoids and peat. 

Figure 15. Characteristics of surface sediment samples from transects across the central region of the fracture zone. Size-distribution histograms have a vertical percentage scale and horizontal size scale (G - gravel, >2mm; S - sand, 2 mm-63μm; SL - silt, 63-4μm; C - clay, <4μm).

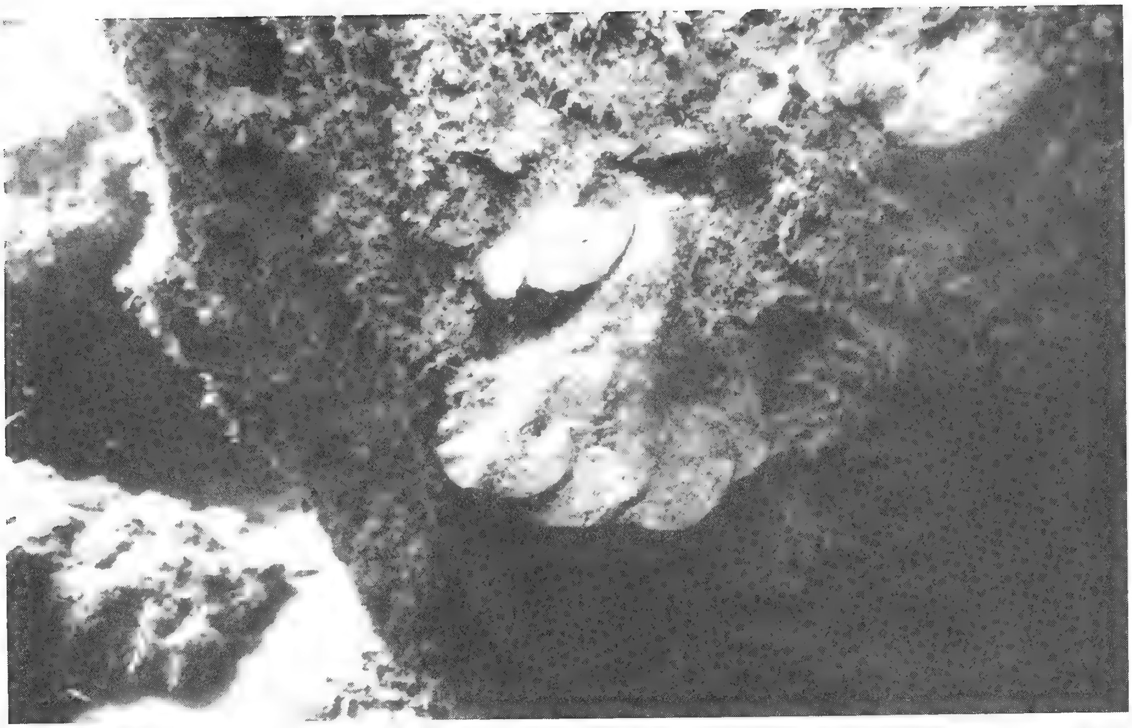


Figure 16. Population of *Lobophora variegata* (shelf form) on vertical fractured peat wall.

Figure 17. Characteristic rhizophytic algae rooted in soft bottoms of fractured depressions.

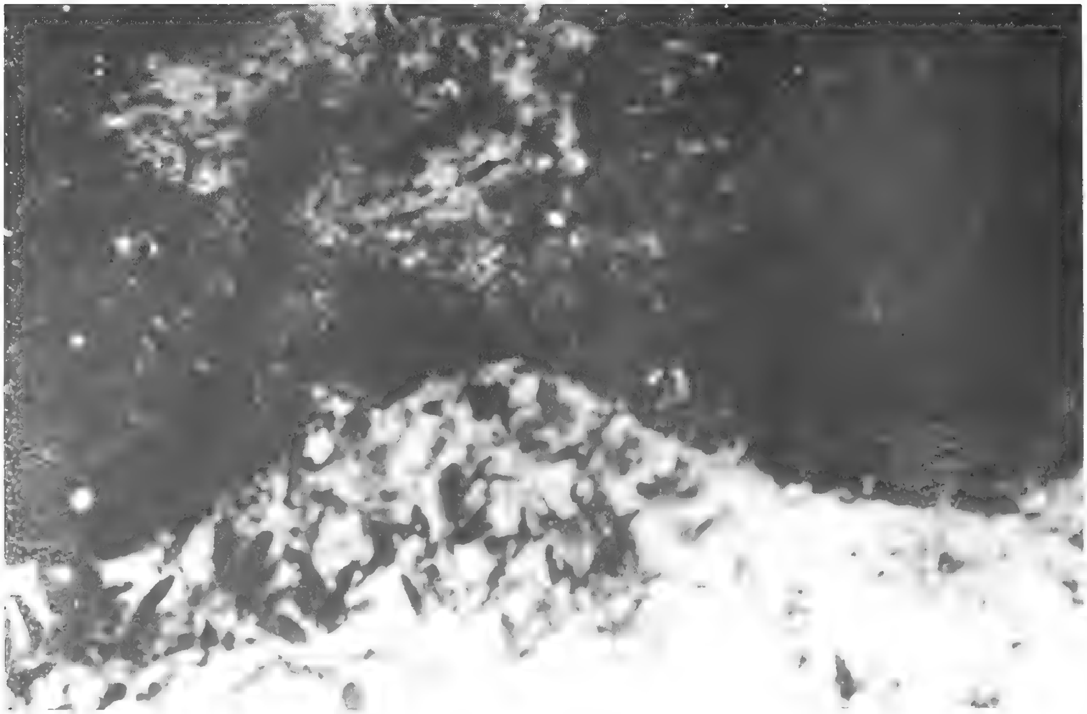


Figure 18. Population of *Halophila decipiens* characteristic of sedimentary bottoms within fractures.

Figure 19. Drift blades of *Thalassia testudinum* accumulating in fracture depressions.

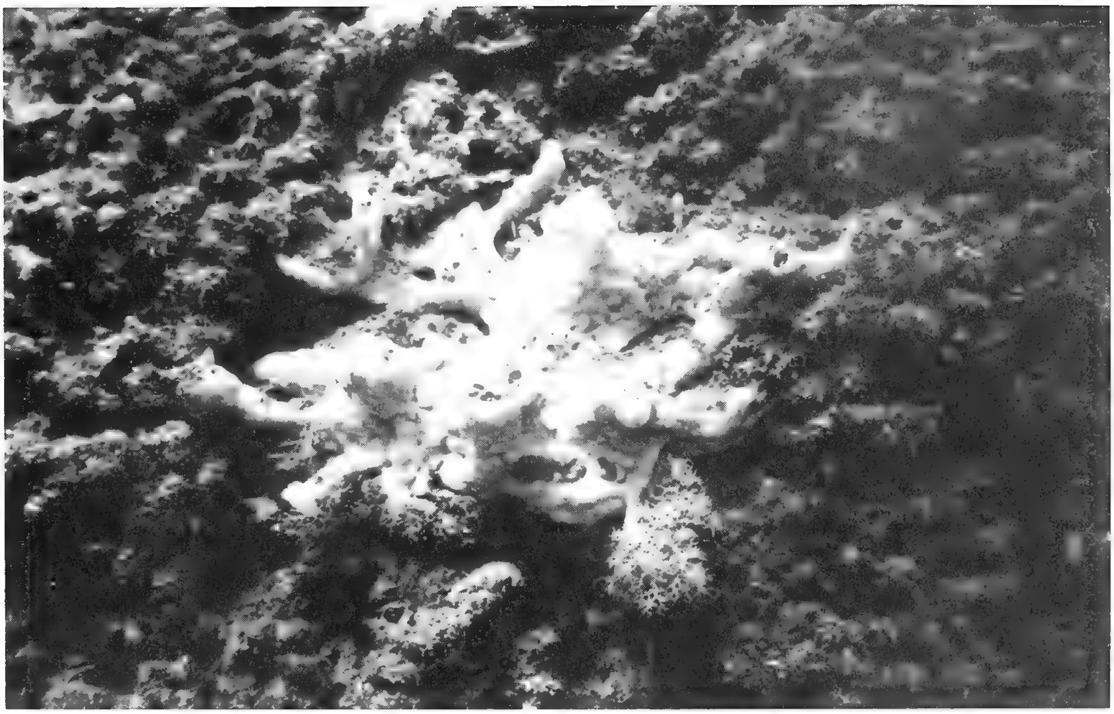


Figure 20. The yellow sponge *Mycale laevis* conspicuous on fracture walls.

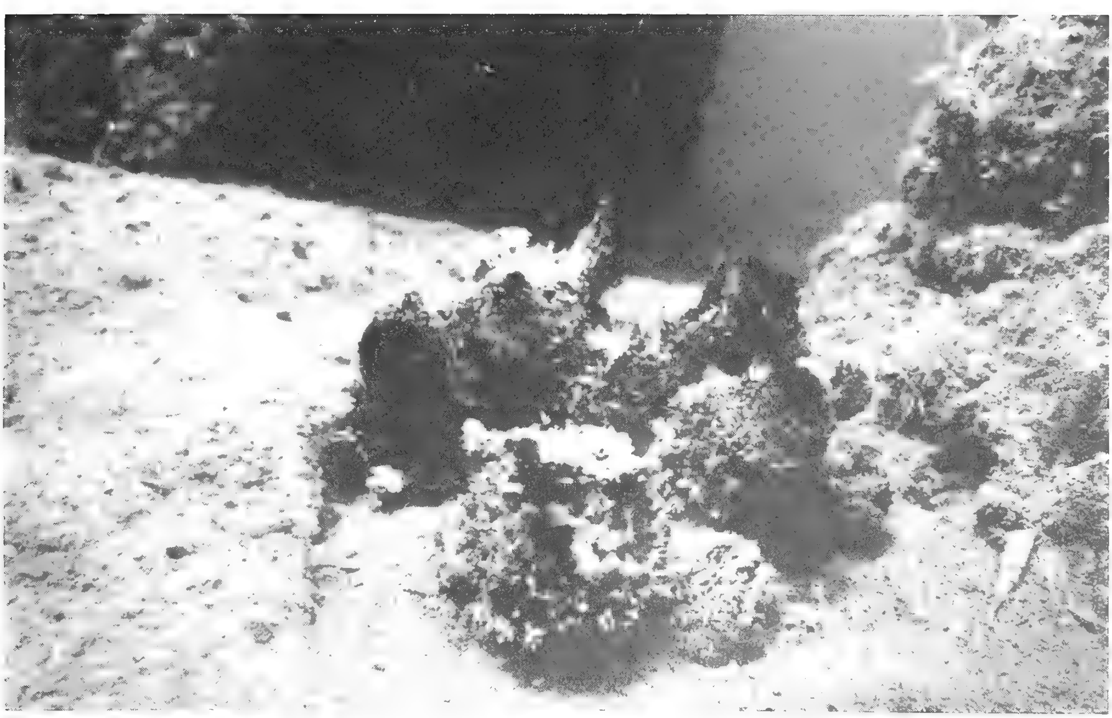


Figure 21. The burgundy sponge *Mycale laxissima* common within fractures.

Figure 22. The orange tunicate *Ecteinascidia turbinata* common within the fracture zone, but otherwise rare in nearby mangrove and reefal habitats.

Figure 23. Medusa of *Casiopea xanachuna* abundant on the muddy peat bottoms of fractures.

Figure 24 A & B. Burial of the southern stingray *Dasyatis americana* (A) causes considerable bioturbation (B) of the soft sediments.

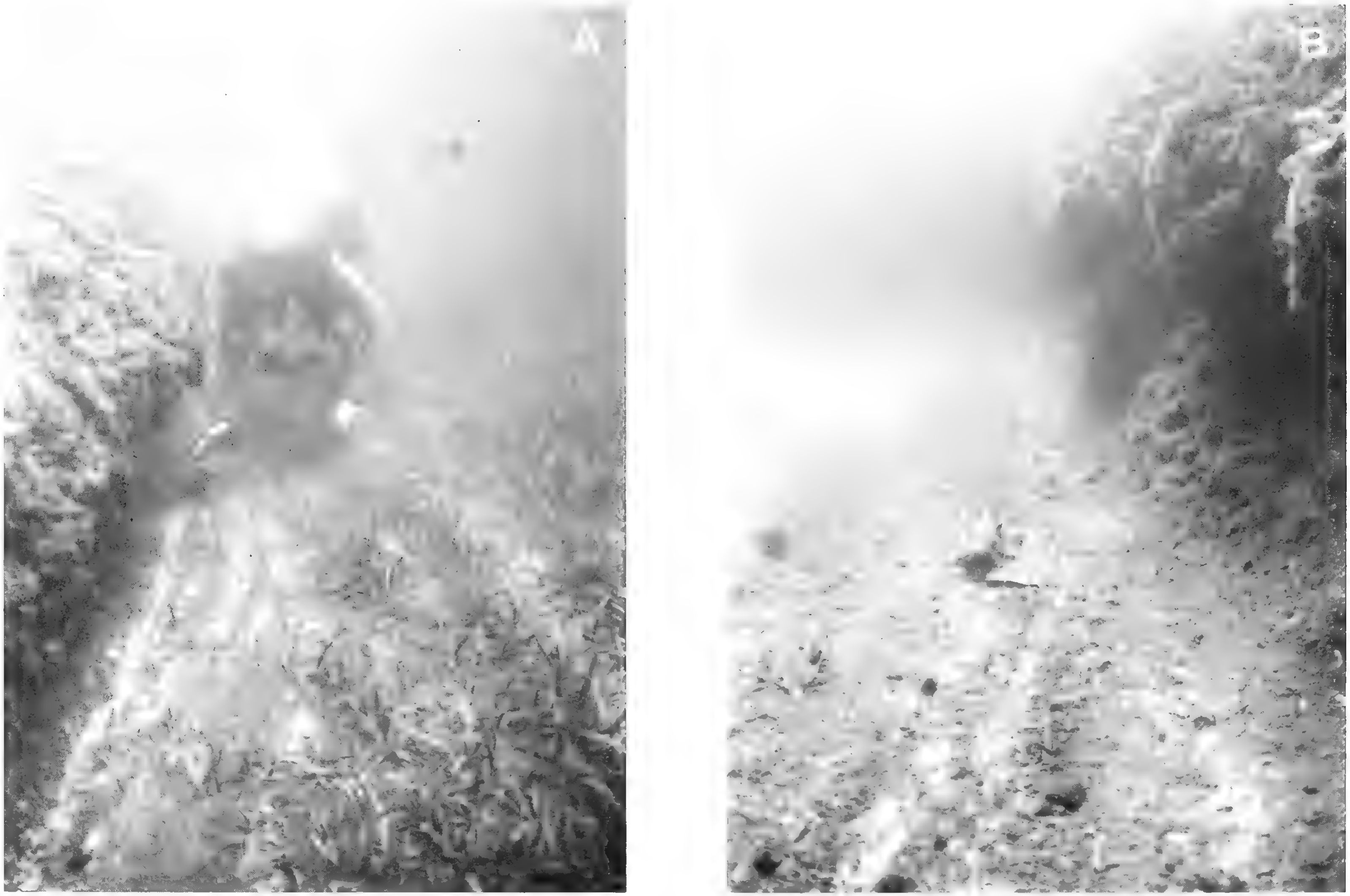


Figure 25 A & B. "Interior halos" created by trapped living gastropods (A), which ultimately die leaving behind grooved tracks of bioturbation (B).

Figure 26. The deep sea urchin *Astropyga magnifica* (new record for Belize) from one of the southwestern fractures.

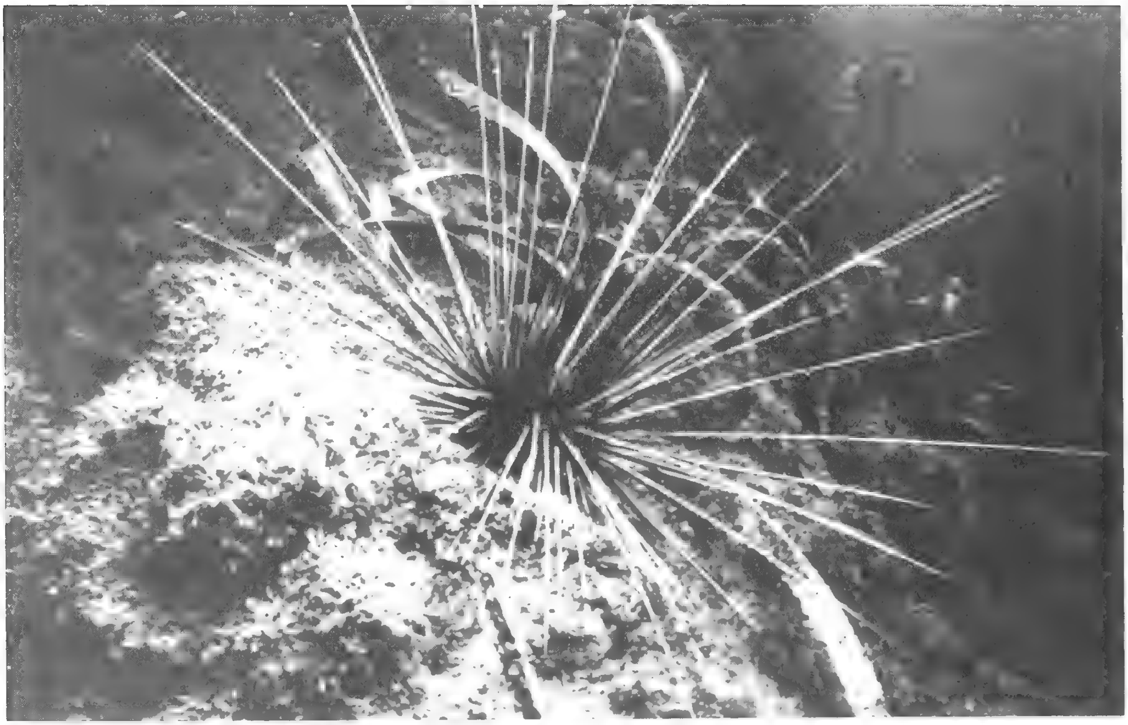


Figure 27. The long-spined urchin *Diadema antillarum* commonly found in the fracture zone and elsewhere.

Figure 28. Aerial view of seismic blast sites (straight line of white sand patches in lower left) from petroleum exploration in vicinity of Tobacco Range.

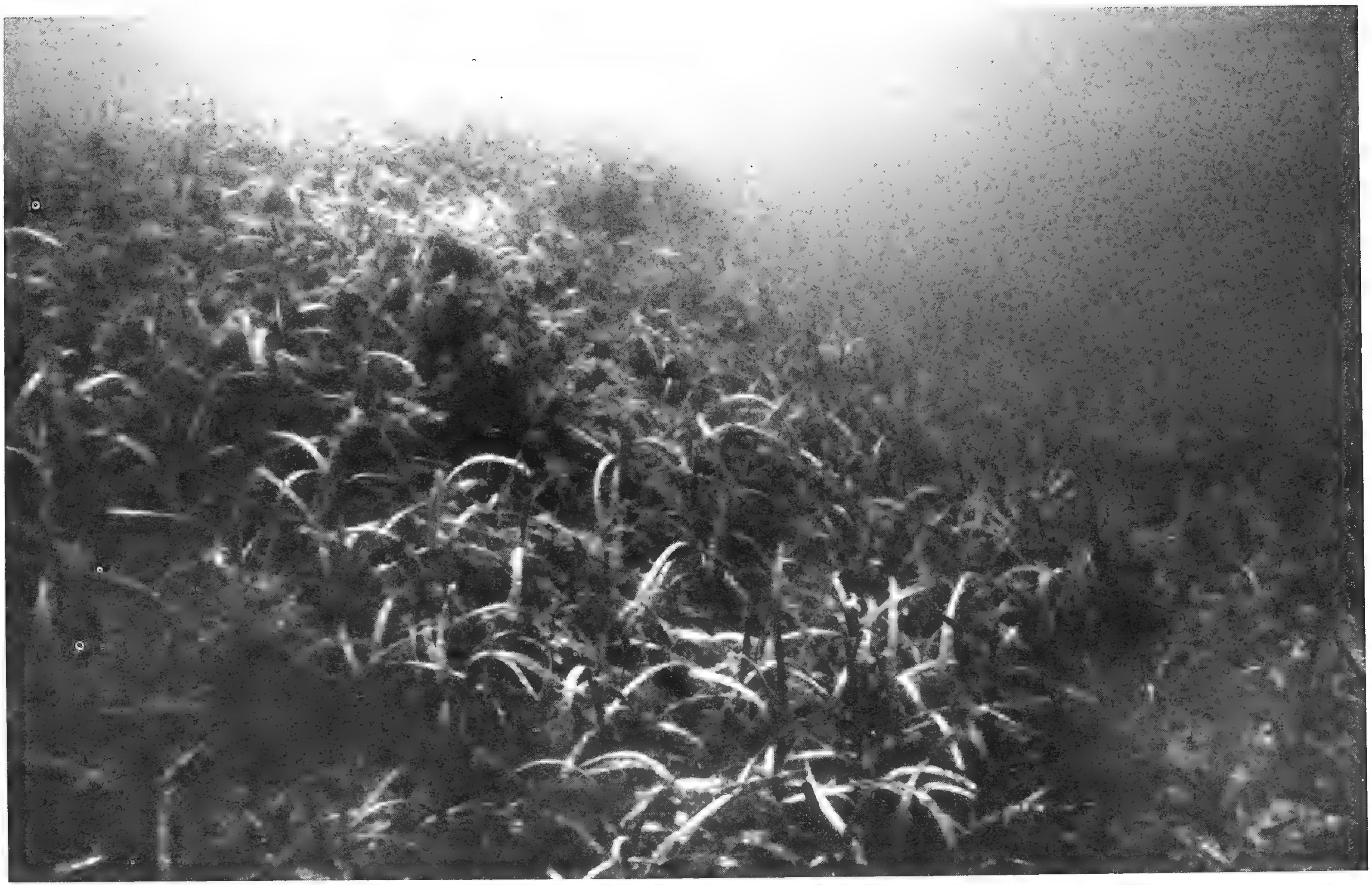


Figure 29. Subdued relief of slumped peat at the outer limits of the fracture zone. All eroded surfaces have been recolonized by the *Thalassia testudinum* community.

ATOLL RESEARCH BULLETIN

NO. 429

MARINE ALGAE AND SEAGRASSES FROM THE TOBACCO RANGE FRACTURE ZONE, BELIZE, C.A.

BY

D.S. LITTLER, M.M. LITTLER, AND B.L. BROOKS

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WASHINGTON, D.C., U.S.A.
AUGUST 1995

MARINE ALGAE AND SEAGRASSES

FROM THE TOBACCO RANGE FRACTURE ZONE, BELIZE, C.A.

BY

Diane S. Littler, Mark M. Littler & Barrett L. Brooks

ABSTRACT

Sixty three species of marine macrophytes (61 algae and 2 vascular plants) were found in the habitats within and surrounding the fractured peat zone of Tobacco Range, a previously unrecognized ecosystem of the Central Province of the Belize Barrier Reef. Of the algae, 35 are Chlorophyta, 22 Rhodophyta, and 4 Phaeophyta; 14 taxa are new records for Belize. All taxa are fully documented, illustrated, and described in detail to provide a utilitarian guide for field identification.

The fracture bottoms contained eight unique species, all of which were psammophytic Chlorophyta, not found on the vertical fracture walls or surrounding seagrass habitat. The fracture walls supported 4 Chlorophyta and 2 Rhodophyta not found in the fracture bottoms or seagrass beds; whereas, the adjacent seagrass beds included 12 Rhodophyta and 3 Chlorophyta not found in the fractured peat habitats. Nine Chlorophyta, two Phaeophyta, and one Rhodophyta were common to all three habitat types. Between-fracture floristic differences were minor and related to the age and size of the fractures. Because of a conspicuous reduction in macrophytic cover and a shift to domination by slower-growing calcareous rhizophytic forms, we hypothesize that the fracturing process is resulting in a considerable loss to total ecosystem primary productivity.

INTRODUCTION

The Belize Barrier Reef complex ranges from 10 to 32 km wide and is about 200 km in length (Rützler and Macintyre, 1982), containing hundreds of mangrove islands, diverse intertidal and subtidal barrier and patch reef zones, two large atolls, and vast lagoonal seagrass beds. However, knowledge concerning the benthic plant communities of these and mainland habitats is at a rudimentary level, especially in light of the developing nature of Belize and its emerging popularity with the diving and scientific communities. Only three algal floristic accounts have been published and include the works of Taylor (1935, documenting 84 marine algae), Tsuda & Dawes (1974, listing 104 marine plants collected at Glovers Reef), and Norris & Bucher (1982, treating 165 taxa of benthic marine algae from the vicinity of Carrie Bow Cay, Southwater Cay, and Twin Cays). Specialized generic treatments have added additional taxa new to Belize; i.e., 7 *Polysiphonia*, Kaprann & Norris (1982); 7 *Udotea*, Littler & Littler (1990); 1 *Anadyomene*, Littler & Littler (1991); 8 *Avrainvillea*, Littler & Littler (1992).

Department of Botany, National Museum of Natural History, MRC#166, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

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STUDY AREA AND METHODS

The unique ecosystem created by the fractured and subsiding fossil mangrove-peat banks on the northwest margin of Tobacco Range (Fig. 1) provided an interesting contrast in habitat types (fracture bottom, fracture walls, and seagrass beds) and was the impetus for this comparative taxonomic investigation. The physiographic characteristics of the fractured peat zone are described by Littler et al. (1995 this volume). To our knowledge, no other studies of comparable fractured mangrove-peat habitats have been performed.

We collected intensively all major marine algae in the eastern, central, and western fractures (Fig. 1) within the three major habitat types from 16 to 20 February 1993 using SCUBA. All material was returned to the laboratory where it was identified, sorted to species while fresh, numbered, and fixed in 5% buffered Formalin. Specimens were later transferred to 70% alcohol for long-term storage.

All taxa present were described and illustrated in detail and arranged in phylogenetic order for higher taxa following Wynne (1986), with the species appearing alphabetically. New records for Belize are designated with asterisks. All identifications were checked against the original published descriptions. Descriptions are representative of the entire species and are not restricted to those specimens from the fracture zone. Species names are followed by citation of the original publication and the basionym with its reference is then given below, if the species is based on an earlier name. The thallus description appears next and includes the macroscopic characters of the organisms presented in easily understood terminology (i.e., we attempted to eliminate technical jargon). The following anatomical descriptions of the microscopic characters (second paragraph) required us to use some specialized technical terms, but these were kept to a minimum and are defined when first used. Specimens cited are only those collected during this specific study and are deposited in the Algal Collection, United States National Herbarium, Department of Botany, National Museum of Natural History, Smithsonian Institution (US).

CHLOROPHYTA

Siphonocladaceae, Siphonocladales

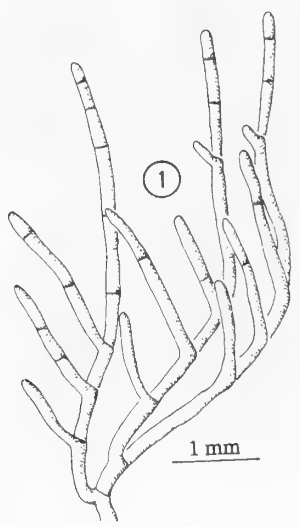
Cladophoropsis membranacea (C. Agardh) Bϕrgesen 1905: 289, figs. 8-13.

Conferva membranacea C. Agardh 1824: 120.

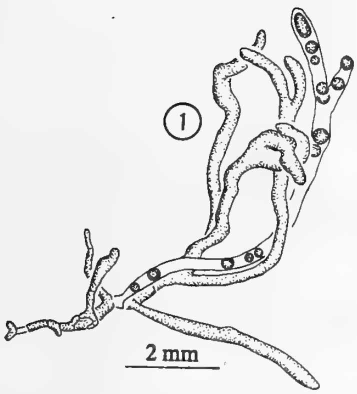
Thallus filamentous forming dense mats or in mixed turfs; mostly 2-5 (up to 10) cm tall; light green, glossy; branching alternate below, unilateral above; attaching filaments horizontally spreading, pale or colorless, entangled, fibrous.

Main filaments 150-280 μm diam.; branchlets 100-150 μm diam., originating from upper end of parent cell; wall formation irregular at long intervals; wall absent from base of branchlet, in open connection to parent cell; attaching filaments often terminating in tenacula-like cells (finger-like pads).

Fracture zone specimen: Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25160* (US).



1. Filaments - showing lack of wall at base of branchlet with open connection to parent cell.



1. Habit of plant - clear filament is reproductive.

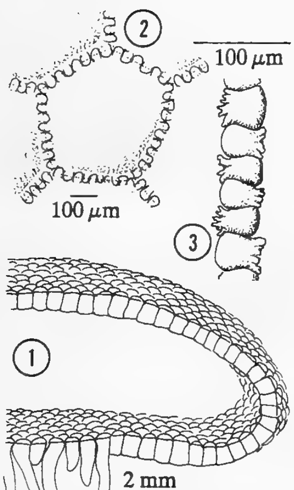
***Siphonocladus rigidus* Howe 1905a: 244, pl. 13, fig. 1; pl. 14, figs. 1-10.**

Thallus coarsely filamentous, crisp, rigid, cushion-like; to 5 cm long; pale to translucent green; main axis indistinct; branching unilateral or irregular; branchlets blunt, not tapered, often growing downward; attached by similar filaments.

Main axis 350-1150 μm diam.; branches single series of cells, rarely 2-3 cells wide; branch cells elongate laterally to form branchlets; branchlets 350-900 μm diam., walls conspicuously thick, 15-70 μm; reproductive structures common, as bright yellow-green spheres formed within filament sheath, spheres slowly released at branch apex.

Fracture zone specimen: Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25171* (US).

Valoniaceae, Siphonocladales



1. Cross section. 2. Surface view - macroscopic cells with connecting tenacular cells. 3. Surface view - tenacular cells.

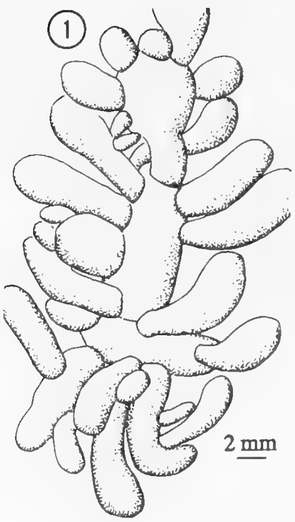
***Dictyosphaeria cavernosa* (Forsskål) Bφrgesen 1932: 2, pl. 1, fig. 1.**

Ulva cavernosa Forsskål 1775: 187.

Thallus sack-like, hollow, spherical when young, irregularly lobed, ruptured when old; to 12(-30) cm diam.; light green; cells macroscopic, in one layer, honeycomb-like, angular or polygonal in surface view; rhizoids short, branched or unbranched.

Cells 0.1-3.0 mm diam., adhering to one another by minute tenacular cells; tenacular cells form continuous row adjacent to large cells, alternately opposite one another.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25099* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25040* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25136* (US).



1. Habit of plant.

Valonia macrophysa Kützing 1843: 307.

Thallus of large macroscopic, crowded cells; of indeterminate diameter, to 5 cm thick; shiny, dark olive-green; rhizoids extending from basal cells.

Cells tightly packed, 5-15 mm diam., 1-4 cm long, spherical, oblong to club-shaped; cell wall thin, tough, elastic; branching irregular, from base or any exposed area.

Fracture zone specimens: Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25027* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25138* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25048* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25169*.

1. Habit of plant - base with rhizoidal cells and vegetative propagules.

Ventricaria ventricosa (J. Agardh) Olsen & West 1988: 104, figs. 1-4.

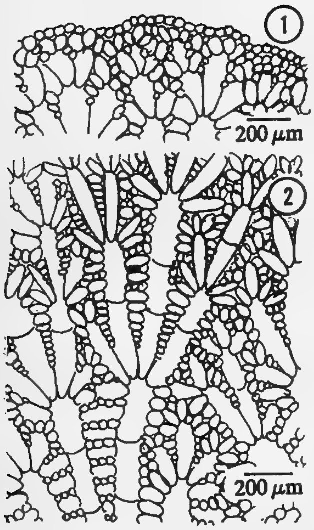
Valonia ventricosa J. Agardh 1887: 96.

Thallus single solitary macroscopic cell or several loosely connected; cells large, unbranched, balloon-like; to 5(-10) cm diam.; shiny, dark green, iridescent, with reflective glare; cells spherical to oblong, hard, firm; rhizoidal cells minute, branched.

Cell wall thin, tough, elastic; reproduction by release of small, juvenile, cytoplasmic spheres from parent cell or expansion of rhizoidal cell.

Fracture zone specimens: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25134* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25164* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25079* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25195* (US).

Anadyomenaceae, Cladophorales



1. Margin of plant. 2. Cell arrangement - note parallel cells between veins.

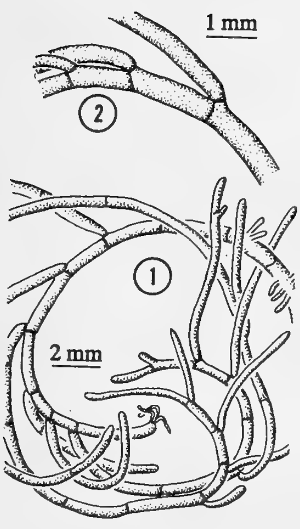
Anadyomene stellata (Wulfen) C. Agardh 1822a: 400.

Ulva stellata Wulfen *in* Jacquin 1786: 351.

Thallus densely packed tufts or erect ruffled clumps; to 10 cm tall; bright yellow-green; blades crisp; veins faintly visible, in fan shaped patterns, margins lobed or undulating; rhizoids loosely entangled.

Veins radiating peripherally from base; branching polychotomous at segment apices; vein cells mid-blade length (0.6-3.0 mm) to width (0.25-0.38 mm) ratio highly variable from 8:1 in young to 2:1 in older blades; cells between veins parallel; margin cells small, oval; rhizoids from basal extensions of corticating siphons, attach directly to substratum or intertwined to form multiple stipes.

Fracture zone specimens: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25153* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25028* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25071* (US), *D&M Littler 25072* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25050* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25166* (US).



1. Habit of plant. 2. Unilateral branching pattern.

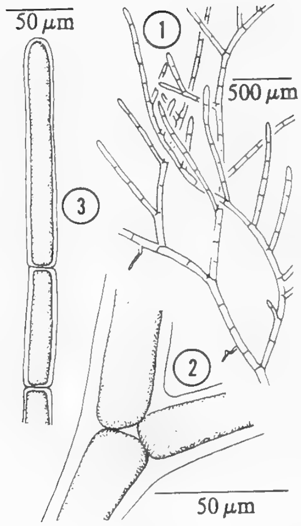
Valoniopsis pachynema (Martens) Børgesen 1934: 10, figs. 1-2.

Bryopsis pachynema Martens 1866: 24, pl. IV, fig. 2.

Thallus filamentous, coarse, stiff, loose, entangled, forming pad-like cushions; to 8 cm diam., 3 cm thick; glossy green; branching generally unilateral; attached by small sparse rhizoids, older branches often secondarily attached by short lateral branchlets.

Main filaments cylindrical, 0.3-1.0 mm diam., 2-10 or more diameters long; branchlets cylindrical with no or little taper, originating from upper end of parent cell; wall formation of branchlets basal to main filament.

Fracture zone specimens: Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25056* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25163* (US).



1. Habit of plant. 2. Cell arrangement at branch base. 3. Apex of branchlet.

Cladophoraceae, Cladophorales

**Cladophora albida* (Nees) Kützing 1843: 267.

Annulina albida Nees 1820: index [1].

Thallus filamentous, undulating, spongy; to 10(-40) cm tall; pale yellow-green to dark green; branching irregular to dichotomous below, unilateral above, at apex of parent cell; branches gracefully curving or sickle shaped; rhizoids fine, short.

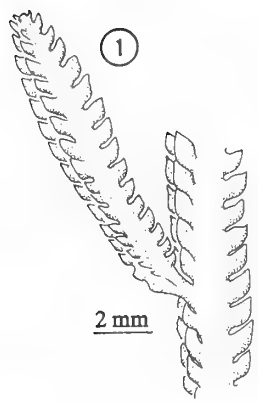
Main filaments cylindrical, to 40(-80) μm diam., 2-7 diameters long; branchlets cylindrical, tapering to 12 μm diam.; cell division primarily intercalary (between cells), not apical.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25070* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25104* (US).

Caulerpaceae, Bryopsidales

Caulerpa cupressoides (West in Vahl) C. Agardh 1822a: 441.
[var. *cupressoides*]

Fucus cupressoides West in Vahl 1802: 38.

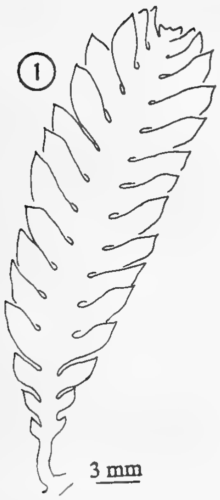


1. Branch with pointed, knob-like branchlets.

Frond erect, stiff, densely covered with short, vertically parallel columnar branchlets; small bushy forms 2-8 cm tall, sparsely branched forms to 25 cm tall; grass-green; branchlets knobby, tough, stiff, cone shaped; rhizome creeping, stoloniferous; rhizoids numerous, white-yellow.

Branchlets 1 mm diam., 1.5 mm long, upcurved, apices pointed; branch stalk 1.5 mm diam.; rhizome 1.5-2.5 mm diam.; rhizoids numerous, thickly stalked, branching to slender apices.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25063* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25106* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25103* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25184* (US).



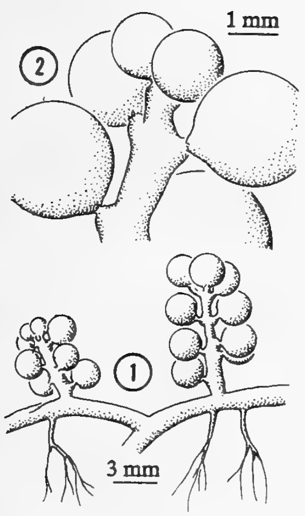
1. Upright with flattened, upturned, pointed branchlets.

Caulerpa mexicana Sonder in Kützing 1849: 496.

Frond erect, resembling flattened feathers; highly variable, dwarf forms to 2 cm tall, 4-10 mm wide in wave-exposed areas, elongated forms 15-25 cm tall, 5-16 mm wide in calm protected habitats; grass-green; unbranched or occasionally branched; branchlets opposite, flattened, upcurved, apices tapering, pointed, base narrows into flat, broad (1-3 mm) midrib; rhizome creeping, stoloniferous; rhizoids delicate, branched.

Branchlets flat, 2(-3) mm wide., 2-10 mm long; stalk 1 mm diam., to 5 mm long; rhizome 0.5-1.25 mm diam,; rhizoids numerous, slender, finely branched.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25078* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25185* (US).



1. Frond with spherical branchlets. 2. Spherical branchlet - note constriction at junction with stalk.

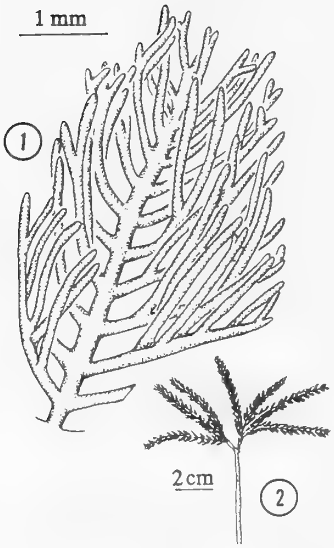
Caulerpa microphysa (Weber-van Bosse) J. Feldmann 1955: 430.

Caulerpa racemosa f. *microphysa* Weber-van Bosse 1898: 361, pl. XXXIII, fig. 5.

Frond bearing clusters of small, spherical to tear shaped branchlets; to 30 mm tall; grass-green; rhizome spreading, creeping, stoloniferous; rhizoids numerous, branched, tapering to slender apices.

Branchlets spherical, to 2.5 mm diam., constricted at base; branchlet stalks to 0.5 mm long, 45°-90° angle from branch; rhizome 1.5 mm diam.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25073* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25110* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25005* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25186* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.93, *D&M Littler 25168* (US).



1. Branch - opposite branchlets with alternate ultimate branchlets. 2. Habit of plant.

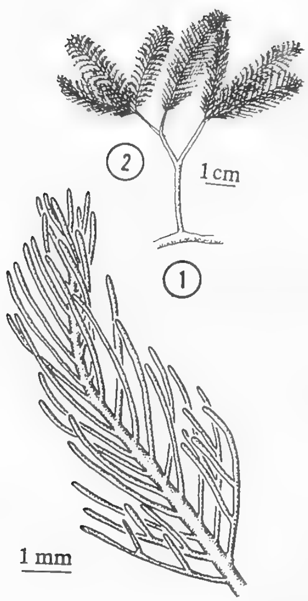
Caulerpa paspaloides* var. *phleoides (Bory de Saint-Vincent) J. Agardh 1849: 500.

Chauvinia phleoides Bory de Saint-Vincent 1829: 205, pl. 23.

Frond erect; to 7 cm tall; stipe naked, green, often branched near midpoint, forked 3-5 times at summit; summit branches 3-6 cm long, dark green, densely covered with fine branchlets set in 3-4 vertical rows, triangular or square configuration when viewed from tip; rhizome creeping, stoloniferous; rhizoids numerous, initially thick, to 1 mm diam., branching to slender apices, white-yellow.

Branchlets cylindrical, 100-120 μm diam., 2-3 mm long, angling 45-55° from axis, stiff, branching opposite, in two ranks; ultimate branchlets alternate angling 45° or less from one another, appearing unilateral at times; stalk 3 mm diam., to 4 cm long; rhizome 4 mm diam.

Fracture zone specimen: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25061* (US).



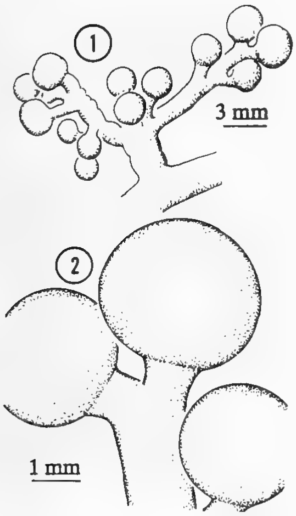
1. Branch - branchlets unbranched except lower 2 sets. 2. Habit of plant.

Caulerpa paspaloides* var. *wurdemanni Weber-van Bosse 1898: pl. XXX, fig. 6.

Frond erect; to 14 cm tall; stipe naked, yellow-green, forked 1-4 times at summit; summit branches 5-10 cm long, dark green, covered with fine branchlets set in 3-4 vertical rows, triangular or square configuration when viewed from tip; rhizome creeping, stoloniferous; rhizoids slender, white-yellow.

Branchlets cylindrical, 160-176 μm diam., 4-6 mm long, opposite, angling 90° from one another, mostly unbranched, lower 2-3 unilaterally branched; stalk 2-3 mm diam., to 6-12 mm long; rhizome 2-4 mm diam.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25084* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25029* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25133* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25162* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25108* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25001* (US).



1. Upright with bulbous branchlets. 2. Spherical branch apex - not constricted at base/stalk junction.

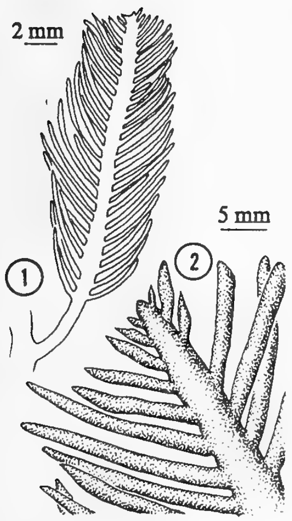
Caulerpa racemosa (Forsskål) J. Agardh 1873: 35.

Fucus racemosa Forsskål 1775: 191.

Frond erect or creeping, bearing small, spherical, bead-like branchlets; 1-15 cm tall; grass-green; rhizomes creeping, stoloniferous, often branched; rhizoids numerous, branched, tapering.

Branchlets spherical, 4 mm diam., stalked, not constricted at base; branch stalk to 2 mm diam.; rhizome 3 mm diam.; rhizoid stalk to 1.5 mm diam., soon branching to fine filamentous apices.

Fracture zone specimen: Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25116* (US).



1. Upright - feather-like in appearance. 2. Apex - note cylindrical aspect of branchlets and main rib.

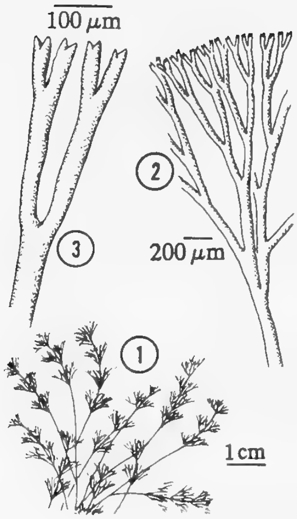
Caulerpa sertularioides (S.G. Gmelin) Howe 1905b: 576.

Fucus sertularioides S.G. Gmelin 1768: 151, pl. XV, fig. 4.

Fronds erect, feather-like, occasionally branched; to 20 cm tall, 1-2 cm wide; light green; branchlets opposite, cylindrical, needle shaped, apices bluntly pointed; rhizomes creeping, stoloniferous, extensive; rhizoids branched, filamentous.

Branchlets 180-330 μm diam., 3-11 mm long, upcurved; stalk 1.0-1.5 mm diam.; rhizome 2.5 mm diam., to 2 m long, generally shorter; rhizoid stalk to 2 mm diam., branching to fine tapering apices.

Fracture zone specimens: Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25117* (US).



1. Habit of plant. 2. Dichotomous branching of branchlet. 3. Forked branchlet apices.

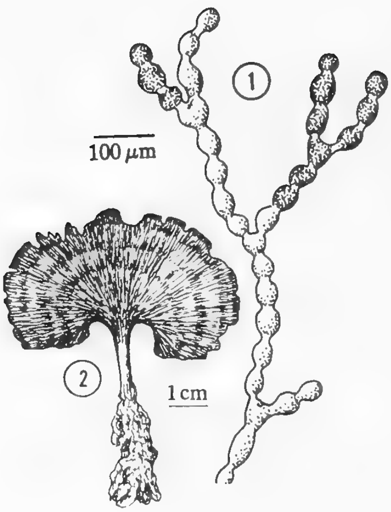
Caulerpa verticillata J. Agardh 1847: 6.

Thallus fine, fibrous, felt-like mats, rarely as individual strands; of indeterminate area, to 7 cm tall; dark green; fronds delicately whorled, 5-8 mm diam.; rhizomes creeping, stoloniferous, slender; rhizoids few, branched.

Branchlets 5-7 times dichotomous, 100-210 µm diam. at base, 30-40 µm at apex, lower segments 10 or more diameters long; apices abruptly forked, pointed; stalk 140-200 µm diam.; rhizome to 560 µm diam.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25064* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25057* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25122* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25017* (US).

Udoteaceae, Bryopsidales



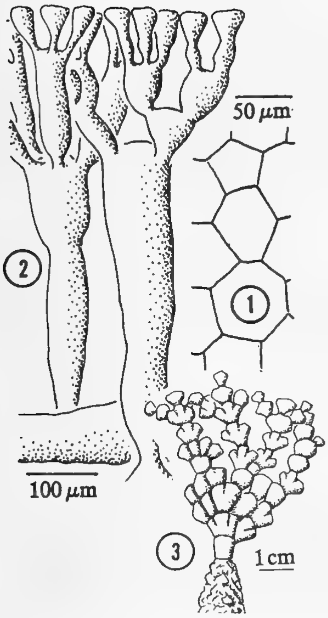
1. Surface siphon of blade. 2. Habit of plant

Avrainvillea nigricans f. *parva* D.S. Littler & M.M. Littler 1992: 402, fig. 17.

Thallus solitary, seldom clustered; to 16 cm tall; pale green to brown-green, fringed in black; mature blades kidney shaped to oval, 15 cm long, 23 cm wide, thin (<2 mm), loosely woven; margins smoothly rounded, lacerate, or ragged; blade base flat or lobed; zonation faint; stipe to 1-4(-9) cm long, narrow, cylindrical, seldom branched; rhizoidal mass bulbous.

Blade inner siphons 30-40 µm in diam., moniliform; blade surface siphons 20-30 µm diam., deeply moniliform, forming loose cortex; stipe central siphons 30-60 µm diam., slightly moniliform; stipe surface siphons 10-20 µm diam., deeply moniliform.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25089* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25145* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25075* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25047* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25179* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25193* (US).



1. Surface cells of segment. 2. Cross section - utricles. 3. Habit of plant.

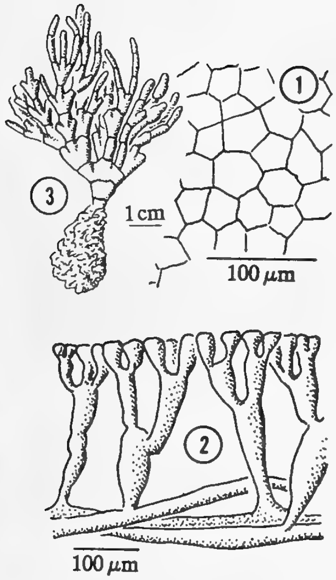
Halimeda incrassata (Ellis) Lamouroux 1812: 186.

Corallina incrassata Ellis 1768: pl. 17, figs. 10-17.

Thallus erect; to 25 cm tall; light to dull green; segments heavily calcified, hard, brittle, disc-like, oval to kidney-shaped, to 14 mm wide, 10 mm long, distinctly ribbed and/or somewhat lobed; basal segments fused; branching somewhat dichotomous, initial branching in one plane; rhizoidal mass bulbous.

Utricles (swollen tips of siphons) in 3-5 layers; surface utricles 34-90(-105) μm diam., 40-125 μm long, 2-4 supported by subsurface utricle; subsurface utricles oval, swollen, 23-90 μm diam., 30-115 μm long; joint siphons uniting as single group; gametangia spherical to oval, bright green, 200-380 μm diam., on dichotomously forked stalk, densely clustered at margins of fertile segments.

Fracture zone specimen: Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25189* (US).



1. Surface cells of segment. 2. Cross section - utricles. 3. Habit of plant.

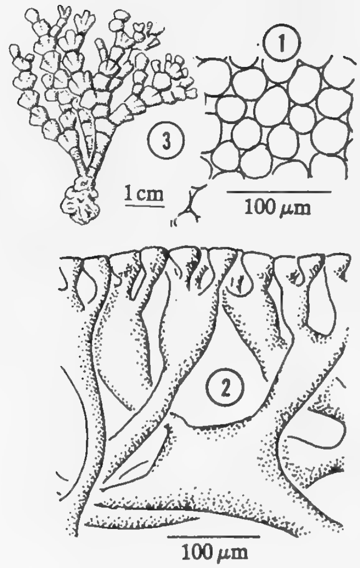
Halimeda monile (Ellis & Solander) Lamouroux 1812: 186.

Corallina monile Ellis & Solander 1786: 110, pl. 20, fig. c.

Thallus erect; to 20 cm tall; dark green; segments calcified, distally cylindrical, elsewhere disc-like or trilobed, 1-5 mm diam., 3-8 mm long; basal segments cylindrical, fused to form stipe; rhizoidal mass bulbous.

Utricles in 3-5 layers; surface utricles 30-60(-80) μm diam., 48-115 μm long, 2-4 supported by subsurface utricles; subsurface utricles 23-90 μm diam., 23-130 μm long; joint siphons uniting in twos, threes, or larger groups.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25098* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25024* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25015* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25188* (US).



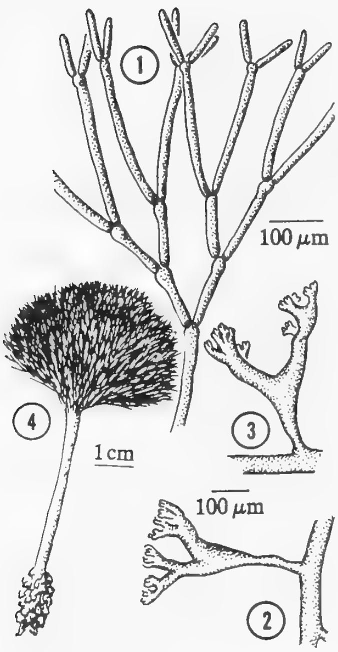
1. Surface cells of segment. 2. Cross section - utricles. 3. Habit of plant

Halimeda simulans Howe 1907: 503, pl. 29.

Thallus erect; to 15 cm tall; light green; segments heavily calcified, hard, disc-like, kidney shaped to oval, trilobed, 4-15 mm wide, 2-11 mm long, distinctly ribbed and/or lobed; basal segment fused, cylindrical, forming short 1-3 segmented stipe; branching somewhat dichotomous, in one plane; rhizoidal mass bulbous.

Utricles in 3-5 layers; surface utricles 25-45(-60) μm diam., 25-90 μm long, rounded triangular, 2-4 supported by subsurface utricles; subsurface utricles variable, swollen, 30-72 μm diam., 30-115 μm long; joint siphons uniting as single group.

Fracture zone specimens: Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25025* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25131* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25112* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25014* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25183* (US).



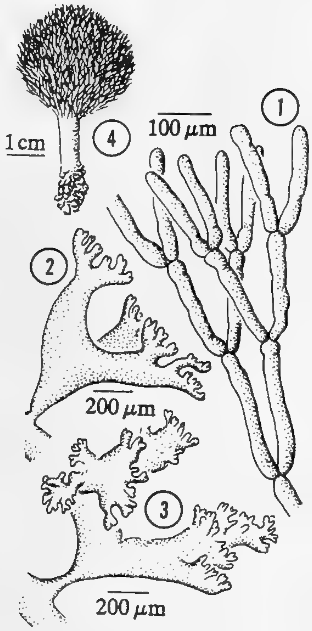
1. Cap siphons. 2 & 3. Lateral appendages of stipe cortex. 4. Habit of plant.

Penicillus capitatus Lamarck 1813: 299.

Thallus bristly, calcified, shaving brush-like; to 18 cm tall; faded green; cap smoothly rounded, spherical to oblong, 2-6 cm diam., as long as broad; cap siphons slender, crowded, dichotomously branched; stipe to 3 mm diam. below, 10 mm diam. above, 14 cm long, seldom branched, surface smoothly corticated; rhizoidal mass bulbous.

Cap siphons 125-300 μm diam., not tapering distally, 2-3 cm long, constricted at all dichotomies, apices slightly swollen; stipe appendages closely set, 4-5 times dichotomous, apices flat, thick.

Fracture zone specimens: Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25113* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25007* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25182* (US).



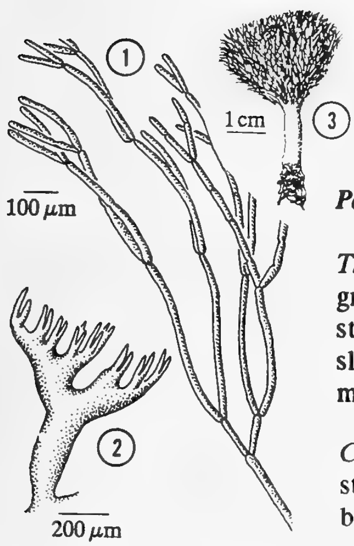
1. Cap siphons. 2 & 3. Lateral appendages of stipe. 4. Habit of plant.

Penicillus lamourouxii Decaisne 1842: 97.

Thallus shaggy, bristly, heavily calcified, shaving brush-like; to 10 cm tall; faded, light green; cap spherical to oval, 2-5 cm diam., as long as broad; cap siphons sparsely scattered, dichotomously branched; stalk unbranched, 5-8 mm diam., 3-4 cm long, often compressed, surface smoothly corticated; rhizoidal mass bulbous.

Cap siphons 300-500 μm diam., stiff, often sporadically moniliform (constrictions at close intervals), constricted above dichotomies; stipe appendages close set, basal branches wide, swollen, dichotomous, apices short, flat.

Fracture zone specimens: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25140* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25077* (US). Wall of central fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25049* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25010* (US).



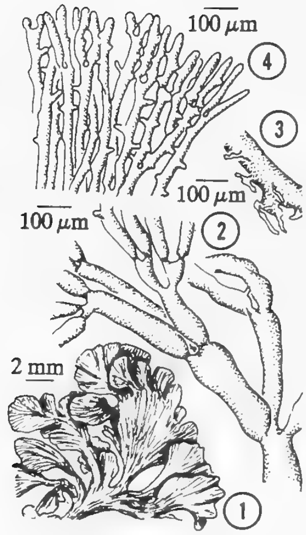
1. Cap siphons. 2. Lateral appendages of stipe cortex. 3. Habit of plant.

Penicillus pyriformis A. Gepp & E.S. Gepp 1905: 1, pl. 468, fig. 1.

Thallus flat topped, heavily calcified, compact, brush-like; to 12 cm tall; gray-green; cap cone shaped, apex flat, sides tapering into stalk; cap siphons stiff, matted or entangled, dichotomously branched; stipe cylindrical or slightly flattened, 5-7 mm diam., 3-10 cm long, rarely branched; rhizoidal mass bulbous.

Cap siphons 150-250 μm diam., 2-3 cm long, constricted above dichotomies; stipe appendages 2-4 times dichotomous, loosely branched, apices tapering, bluntly pointed.

Fracture zone specimen: Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25190* (US).



1. Habit of plant. 2. Basal siphons of blade. 3. Lateral appendages of stipe/rhizome. 4. Blade margin.

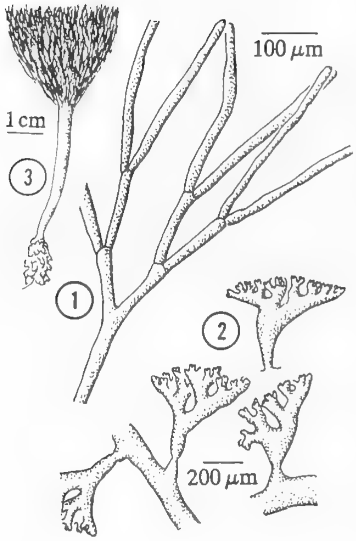
Rhipiliopsis stri (Earle & Young) Farghaly & Denizot 1979: 71.

Siphonoclathrus stri Earle & Young 1972: 3, pls. 1-8.

Thallus in ruffled clumps or turf-like, gregarious; to 8 mm tall; dark to pale green; blades fan shaped, flattened, to 5 mm long, net-like, in one layer; upper stipe of several intertwined siphons, lower stipe single siphon, cylindrical, at times rhizome-like, with short contorted lateral projections; contorted projections developing into rhizoids at base of plant.

Blade siphons 40 μm diam. throughout, cylindrical, parallel, fused laterally by short, lateral branchlets, constrictions above dichotomies symmetrical; stipe siphons 40 μm diam.; stipe appendages loosely packed, repeatedly branched; single connecting stipe/rhizome to 70 μm diam.

Fracture zone specimens: Wall of east fracture, as loose mats, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25065* (US). Wall of central fracture, individual or as loose mats, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25054* (US). Wall of west fracture, as loose mats, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25167* (US).



1. Cap siphon. 2. Lateral appendages of stipe cortex. 3. Habit of plant.

Rhipocephalus oblongus (Decaisne) Kützing 1849: 506.

Penicillus oblongus Decaisne 1842: 97.

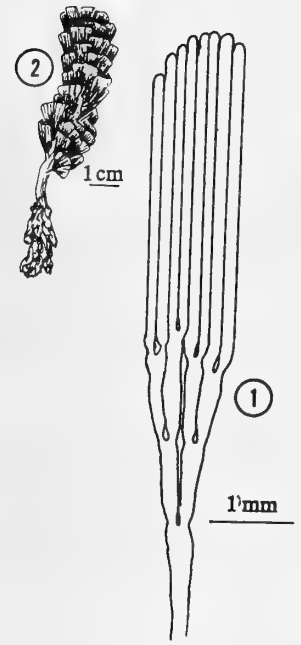
Thallus bristly, lightly calcified, flat-topped or shaving brush-like; to 20 cm tall; dark green; cap cone shaped, lower edge straightly angled from stipe, 1-3 cm diam., to 5.5 cm long; cap apex smoothly rounded, flat or concave; cap siphons slender, free, not fused, dichotomies equal distances from base, symmetrical branching in one plane; stipe 6 mm diam., 4.0-7.5 cm long, penetrating to apex, seldom branched; rhizoidal mass compact.

Cap siphons 200-350 μm diam. proximally, tapering to 160 μm diam. distally, 7-15 mm long; basal segments shorter, lower 1 or 2 dichotomies not constricted; outer segments longer, constrictions above dichotomies symmetrical; stipe appendages 5-7 times divided, apices blunt, finger-like.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25062* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25109* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25002* (US).

Rhipocephalus phoenix (Ellis & Solander) Kützing 1843: 311. [f. ***phoenix***]

Corallina phoenix Ellis & Solander 1786: 126, tab. 25, figs. 2, 3.

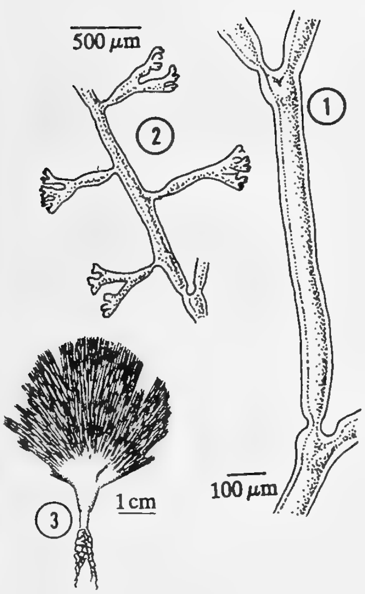


1. Cap siphons. 2. Habit of plant.

Thallus cap cylindrical, lightly calcified; to 10 cm tall; dark green; cap blades concentric, flattened, to 5 cm long, symmetrical, in close proximity to main stalk; blade siphons cylindrical, parallel, fused laterally, dichotomies equal distances from base; stipe cylindrical, corticated, often long; rhizoidal mass compact.

Blade siphons 200-250 μm diam. proximally, 50-100 μm diam. distally, constrictions above dichotomies symmetrical; stipe appendages tightly packed, repeatedly branched, apices blunt, finger-like.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25096* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25037* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25139* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25074* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25046* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25177* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25121* (US). Bottom of central fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25003* (US).



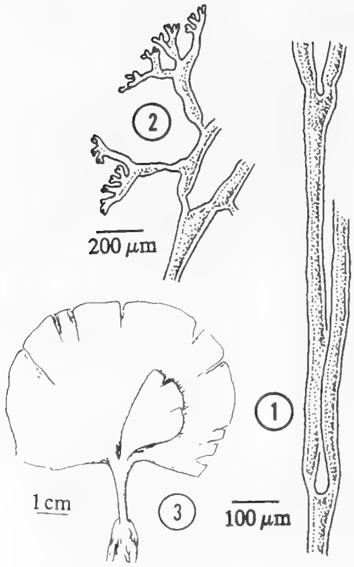
1. Blade siphon. 2. Stipe siphon with lateral appendages. 3. Habit of plant.

Udotea abbottiorum D.S. Littler & M.M. Littler 1990: 210, fig. 1.

Thallus narrowly fan shaped, calcified; to 15 cm tall; yellow-green, growing margin often darker green; blade to 5 cm wide, 8 cm long, 1-3 mm thick; cortex absent; zonation obscure with age; stipe cylindrical, flattened above, gradually widening into blade; rhizoidal mass bulbous, entangled.

Blade siphons lacking lateral appendages, 90-110 μm diam., constrictions above dichotomies symmetrical; stipe siphons 70-100 cm diam.; stipe appendages repeatedly dichotomous, apices flattened in lower stipe, swollen in upper stipe.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25091* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25142* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25068* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25178* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25115* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25198* (US).



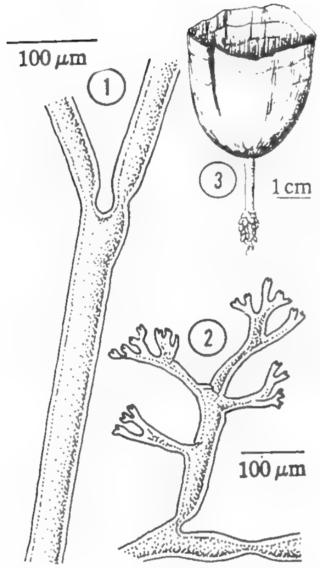
1. Blade siphon. 2. Stipe siphon with lateral appendages. 3. Habit of plant.

Udotea caribaea D.S. Littler & M.M. Littler 1990: 211, fig. 2.

Thallus widely fan shaped, heavily calcified; to 9 cm tall; yellow or white-green, ash-white when dried; blade to 10 cm wide, 7 cm long, 0.5-1.0 mm thick; cortex absent; zonation obscure; stipe 2-5 mm diam., to 2.5 cm long, no clear demarcation between stipe and blade surface texture; rhizoidal mass bulbous, entangled.

Blade siphons lacking lateral appendages, tightly compact, 30-50 µm diam., constrictions above dichotomies symmetrical; stipe siphons 60-80 cm diam.; stipe appendages repeatedly branched, apices stubby, digitate, blunt.

Fracture zone specimens: Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25107* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25102* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25195* (US).



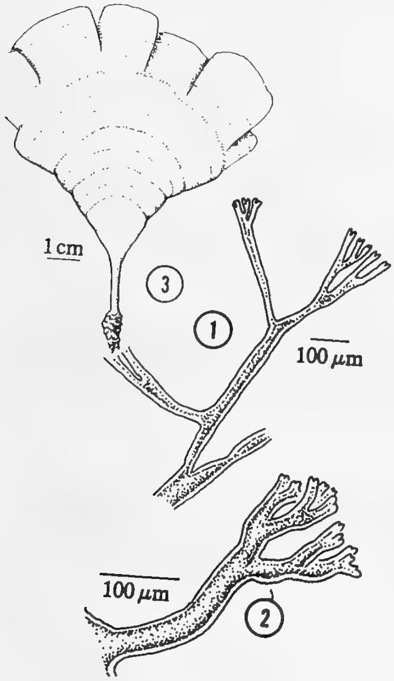
1. Blade siphon. 2. Stipe siphon with lateral appendages. 3. Habit of plant.

Udotea cyathiformis Decaisne 1842: 106.

Thallus cup-shaped, calcified; to 8 cm tall; green; blade delicate, 0.5-1.0 mm thick, fibrous to papery; cortex absent; zonation faint; stipe 1-4 mm diam., 0.3-2.0 cm long, sharp demarcation where blade meets stipe; rhizoidal mass fibrous.

Blade siphons lacking lateral appendages, 30-70 µm diam., parallel to interwoven, constrictions above dichotomies symmetrical; stipe siphons 50-120 µm diam., generally unequally constricted at dichotomies; stipe appendages repeatedly branched, apices swollen or flattened.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25092* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25036* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25141* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25067* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25058* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25120* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25011* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25196* (US).



1. Blade siphon with lateral appendages. 2. Blade lateral appendage. 3. Habit of plant.

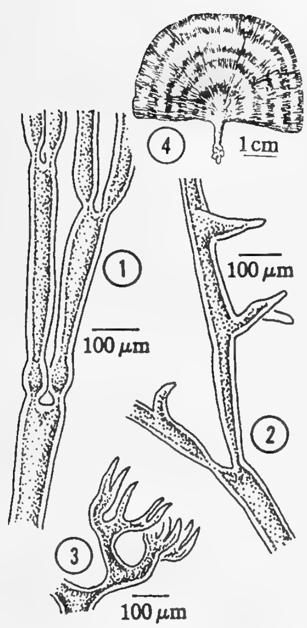
Udotea flabellum (Ellis & Solander) Howe 1904: 94.

Corallina flabellum Ellis & Solander 1786: 124, pl. 24.

Thallus fan shaped, moderately calcified, solitary; to 30 cm tall; dark green to pale green; blade variable, undivided to highly divided, size variable, 0.8-1.5 mm thick, leathery, corticated; zonation distinct; no variations between stipe and blade surface; stipe unbranched, 5-7 mm diam., 2 cm long, cylindrical below, flattened above; rhizoidal mass bulbous to elongated.

Blade siphons 30-50 µm diam., constrictions above infrequent dichotomies absent or slightly asymmetrical; lateral appendages irregularly spaced, long stemmed, dichotomously branched, apices crowded, short, rounded, when dried shrunken or flat; stipe siphons 20-80 µm diam.; stipe appendages similar to blade.

Fracture zone specimens: Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25114* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25008* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25197* (US).



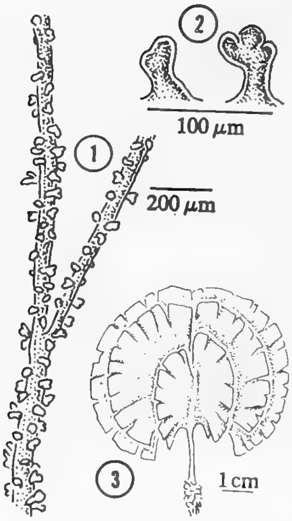
1. Blade siphon. 2. Siphon near base of blade. 3. Stipe lateral appendage. 4. Habit of plant.

Udotea luna D.S. Littler & M.M. Littler 1990: 232, fig. 16.

Thallus fan-shaped to half-moon-shaped, lightly calcified; to 7 cm tall; dark green when young, light green when old; blade broader (6 cm) than long (4 cm), to 1 mm thick; cortex absent; zonation faint; texture velvety when young; margins ragged, often torn or fluted (overlapping one another); base flat to lobed; stipe 1-2 mm diam., 5 mm tall, gradual transition of surface texture from smooth stipe to fibrous blade; rhizoidal mass small, entangled.

Blade siphons lacking lateral appendages, 50-80 µm diam., deep symmetrical constrictions above dichotomies; basal blade siphons possess abbreviated lateral appendages; appendages increasing in density toward stipe; stipe siphons 60-90 µm diam., constrictions at dichotomies slightly uneven; stipe appendages repeatedly branched, apices pointed.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25090* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25143* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25069* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25009* (US).



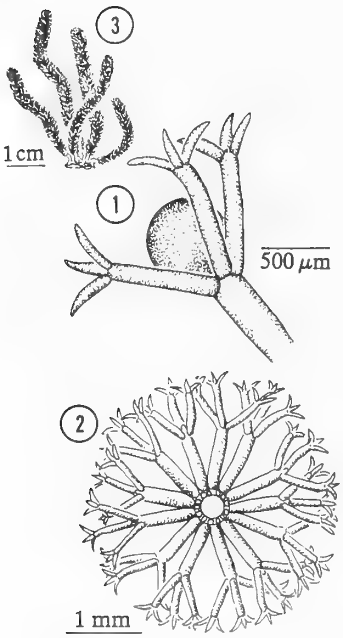
1. Blade siphons. 2. Lateral appendages of blade. 3. Habit of plant.

Udotea wilsonii A. Gepp, E.S. Gepp & Howe in A. Gepp & E.S. Gepp 1911: 130-131, 144, pl. VII, fig. 66; pl. VIII, figs. 67, 67a, 68, 68a. [as *U. wilsoni*]

Thallus of multiple fan shaped blades radiating from central axis (rarely as single flat blade), lightly calcified; to 13 cm tall; dark gray-green; blade wider (10 cm) than long (8 cm), thin (1-2 mm); cortex incomplete; zonation faint; stipe 1-2 mm diam., 1-2(-4) cm long; rhizoids entangled, fine, fibrous.

Blade siphons 40-80 μm diam., constrictions above dichotomies rare, asymmetrical when present; lateral appendages short, knobby, blunt, simple, or forked, 25-90(-120) μm long, in 2-4 vertical rows becoming obscure with age; stipe appendages short, dichotomously branched, apices knobby.

Fracture zone specimen: Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25118* (US).



1. Cross section at whorl of branchlets. 2. Fertile branchlet with solitary, spherical sporangia. 3. Habit of plant.

Dasycladaceae, Dasycladales

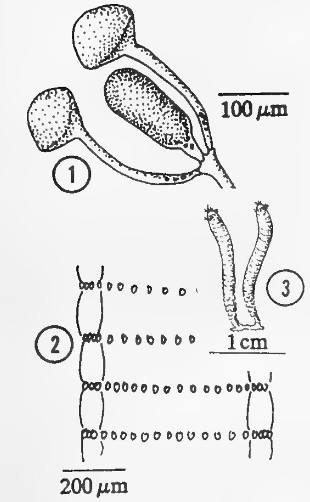
**Dasycladus vermicularis* (Scopoli) Krasser in Beck & Zahlbruckner 1898: 5, fig. 8.

Spongia vermicularis Scopoli 1772: 412, pl. 64, fig. 1454.

Thallus fuzzy, soft, individuals cylindrical, gregarious; 5-8 mm diam., to 6 cm tall; green; main axis whorled with tightly packed, forked branchlets; stipe short, naked; holdfast of short lobes.

Branches in whorls from central axis, 10-15 per whorl; branch basal cell large, capped with 3-4 branchlets, these capped with 3 spine-like branchlets; sporangia 1 per branch, spherical, bright yellow-green, in axis of branchlets.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25100* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25032* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25137* (US).



1. Sporangia flanked by surface cells. 2. Longitudinal section of central axis showing small scars where whorled branchlets were attached. 3. Habit of plant.

Neomeris annulata Dickie 1874: 198.

Thallus solitary or in dense clusters, cylindrical, erect, or arched downward; 1-3 mm diam., 1-2(-3) cm tall; base white, heavily calcified; apex fuzzy green, tufted with apical filaments; surface of polyhedral cells in annular rows; holdfast small, pad-like.

Central axis to 640 μm diam.; apical filaments unbranched, deciduous, fine; branchlets in whorls from central axis, terminating in 2 surface cells flanking sporangia; surface cells with bulbous apex, 80-135 μm diam.; sporangia elongated oval, stalked; spores oval, 46-80 μm diam., 115-175 μm long, at maturity fusing in heavily calcified sets of 5-8(-12); holdfast short, contorted siphons.

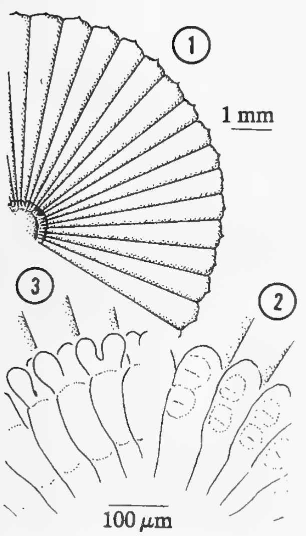
Fracture zone specimen: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, specimen lost after identification.

Polyphysaceae, Dasycladales

Acetabularia crenulata Lamouroux 1816: 249, tab. viii, fig. 1.

Thallus solitary or in clusters, parasol shaped, moderately calcified; 2-8 cm tall; white-green; discs one or more, flat or cup shaped, 12-20 mm diam.; stalk slender; holdfast small, pad-like.

Disc of 30-80 rays, evenly tapered, oval in cross section; outer margin of ray with centered tooth or spine; corona superior (at base of rays) of short inconspicuous projections, apices rounded or slightly lobed, with 2 exceedingly faint hair scars; corona inferior (under side, base of ray) of short inconspicuous projections, apices forked; mature rays forming sporangia; aplanospores 65-80 μm diam., to 500 per ray.

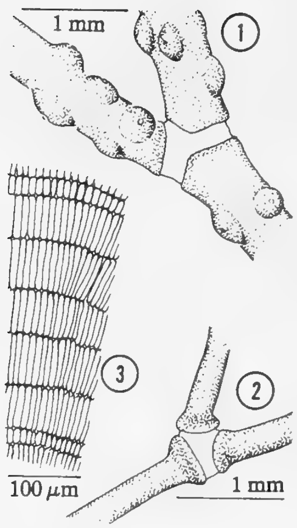


1. Disk of rays. 2. Corona superior with 2 hair scars. 3. Corona inferior with lobed apices.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25093 (US), D&M Littler 25094* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25021 (US), D&M Littler 25022* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25129* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25053* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25173* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25124* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25012* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25191* (US).

RHODOPHYTA

Corallinaceae, Corallinales



1. Mature branch with hemispherical conceptacles. 2. Immature branch - note swollen segment ends. 3. Longitudinal section showing one alternating short to five long cells.

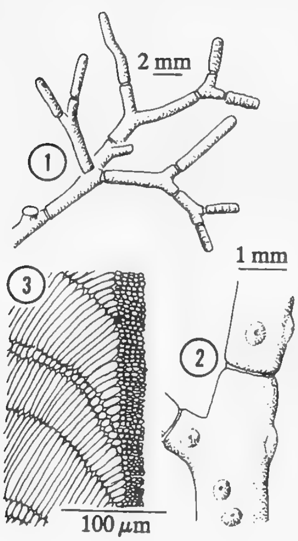
Amphiroa fragilissima **(Linnaeus) Lamouroux 1816: 298.**

Corallina fragilissima Linnaeus 1758: 806.

Thallus entangled, fragile, calcareous, dense clumps or mats; to 8 cm thick; yellow-green to white-pink; branching widely dichotomous, occasionally trichotomous, primarily at uncalcified joints; branches thin, brittle, jointed, cylindrical, often swollen at segment ends; holdfast crust-like, inconspicuous.

Lower segments 150-600 µm diam., 8-20 times as long; medulla 4-8 transverse rows of long cells (55-90 µm long) alternating with 1-2 rows of short cells (15-35 µm long); surface several layers of short cells increasing in thickness with age; joint structure similar; conceptacles lateral on calcified segments, hemispherical, 300-340 µm diam. with terminal pore; tetrasporangia 25 µm diam., 50 µm long.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 250095* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25020* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25130* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25076* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25052* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25165* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25123* (US).



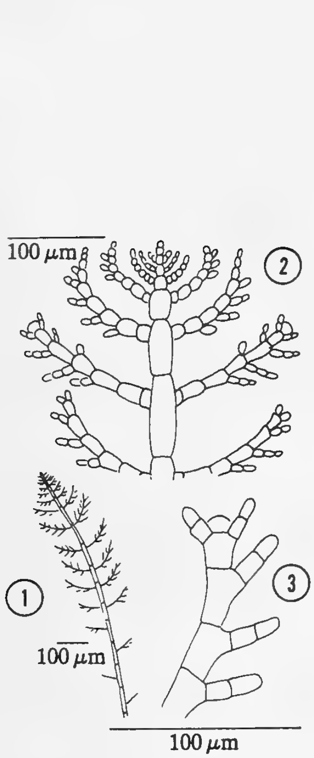
1. Branch showing joints generally not at forks. 2. Mature branch with raised conceptacles. 3. Longitudinal section showing one alternating short to two long cells and smaller surface cells.

Amphiroa rigida **var. *antillana*** **Bϕrgesen 1917: 182, figs. 171-173.**

Thallus open, brittle, heavily calcified clumps; 10-15 cm diam.; light off-white; branching widely dichotomous, joints seldom at forks; branches unequal in length, cylindrical, 1-2 mm diam., not swollen at joints; apices tapered slightly or bluntly rounded, 0.5-1.5 mm diam.; holdfast crust-like, inconspicuous.

Medulla cells alternating between 2 transverse rows of long cells (100 µm long) with 1 row of short cells (20 µm long), aligned in vertical rows - not offset, with blunt apices; surface several layers of short cells increasing in thickness with age; joint cells in 2 transverse sets, thick walled, aligned obliquely - offset, with joining apices pointed; conceptacles lateral, convex, to 250 µm diam. with terminal pore.

Fracture zone specimen: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25151* (US).



1. Habit of plant. 2. Apex showing ultimate branchlets unilateral on lower side of branch, eventually becoming opposite. 3. Terminal gland cell on lateral branch.

Ceramiaceae, Ceramiales

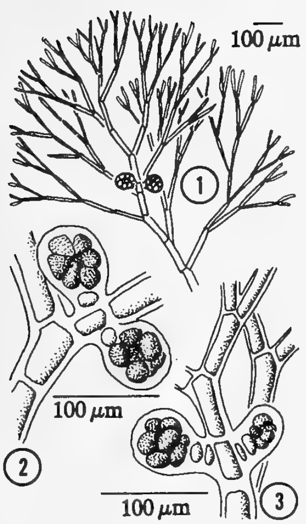
****Acrothamnion butleriae*** (Collins) Kylin 1956: 375.

Antithamnion butleriae Collins 1901: 258.

Thallus fine, delicate, filamentous; to 1 cm tall; translucent, pale red; main branching sparse, irregular; lateral branchlets at first regularly alternate, becoming symmetrically opposite; rhizoids fine, inconspicuous.

Prostrate filaments to 30 µm diam., 100-150 mm long; erect filaments to 30 µm diam., 120 µm long; branchlets proximally forming at point one third along axial cell, distally forming above upper two thirds or higher on axial cell; ultimate branchlets initially unilateral on lower side of branch, soon becoming opposite; gland cells, when present, terminal on lateral branches.

Fracture zone specimens: Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25059* (US). Bottom of east fracture, 7 m deep, epiphytic on larger algae or *Thalassia testudinum*, 16.ii.1993, *D&M Littler 25125* (US).



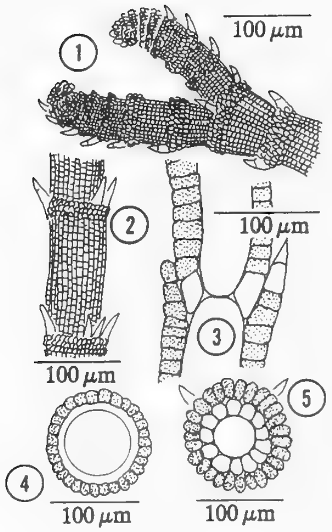
1. Habit of plant. 2 & 3. Paired, opposite gonimoblast masses with dark carpospores.

Callithamnion halliae Collins *in* Collins, Holden, & Setchell 1900: 698.

Thallus filamentous, small, bushy; to 2(-5) cm tall; pale pink; branching alternately spiral proximally, dichotomous distally; rhizoids branched, fine.

Main axis cells to 100(-200) µm diam., 250-600 µm long, tapering distally; apical cells slender, to 6 µm diam., 50 µm long, tips rounded, uncorticated throughout; tetrasporangia pear-shaped, sessile; spermatangial clusters tufted, colorless, on upper side near base of branchlet; gonimoblast masses opposite, at base of branch, to 75 µm diam., dividing into 6-10 darkly pigmented carpospores; gonimoblast stalk short, inconspicuous, of 1-2 cells.

Fracture zone specimen: Seagrass bed of west fracture, 3 m deep, epiphytic on larger algae or *Thalassia testudinum*, 20.ii.1993, *D&M Littler 25154* (US).



1. Branch apex - note incurved apices. 2. Branch with heavily corticated, spined joints. 3. Longitudinal section of joint. 4. Cross section of segment. 5. Cross section of joint.

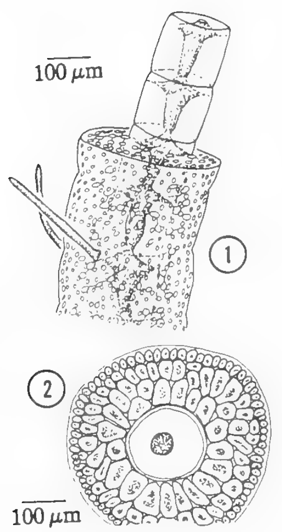
Centroceras clavulatum (C. Agardh) Montagne 1846: 140.

Ceramium clavulatum C. Agardh 1822b: 2.

Thallus filamentous, stiff, entangled; to 20 cm long; dark brown-maroon; branching narrowly dichotomous; apices forked, slightly incurved, pincher-like; rhizoids filamentous, terminating in lobed disc.

Branches 50-200 μm diam., heavily pigmented, darker pigmentation at joints; central filament corticated; surface cells in 1 layer, rectangular, longitudinally aligned; segments 300-500 μm long; joints whorled with spines, 2 layers of corticating cells; spines deciduous or worn away with age; sporangia oval to spherical, tetrahedral, occasionally cruciate, 45-50 μm diam., 50-63 μm long, thick walled, enveloping filaments short, forming at joints; spermatangia in terminal clusters; procarps (carpogonium and auxiliary cell system) formed laterally at joints; carposporangia developing from gonimoblast cells.

Fracture zone specimens: Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25175* (US).



1. Strand structure - inner core filament surrounded by smaller cells. 2. Cross section.

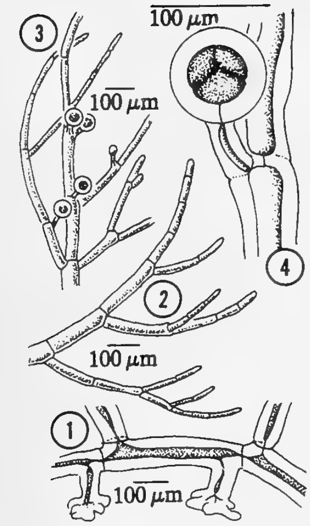
Ceramium nitens (C. Agardh) J. Agardh 1851 [1851-1863]: 130.

Ceramium rubrum (Hudson) C. Agardh var. *nitens* C. Agardh 1824: 136.

Thallus stiff firm strands (occasionally soft and slippery) forming tufts or small entangled clumps; to 10 cm tall; bright rust or rose; branching dichotomous to alternate, widely spreading; apices often secund (branching on outer side only), incurved; rhizoidal mats turf-like.

Strands 130-430 μm diam., central filament cells 2-3 times as long as broad; corticating cells darkly pigmented, obscuring banding characteristic in most *Ceramium*; hairs short (to 1 mm long), straight, often at joints; tetrasporangia random, embedded in surface cells, cruciate (divided in two planes at right angles to one another); cystocarps lateral on upper branches with 3 enveloping filaments.

Fracture zone specimen: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25082* (US).



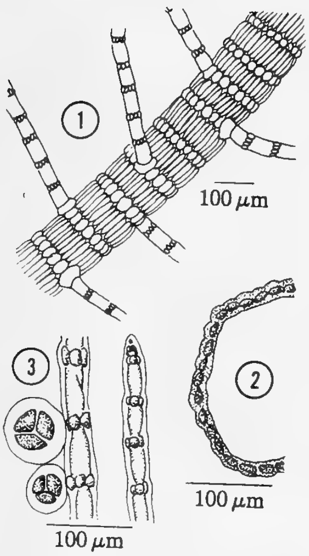
1. Rhizome with unbranched rhizoids. 2. Branch apices with unilateral branchlets. 3. Branch with tetraspores. 4. Tetraspore on unicellular stalk.

Spermothamnion gymnocarpum Howe 1920: 579.

Thallus tufted, small, bushy, filamentous; to 3 cm tall; purple-pink; branching dichotomous below, soon becoming opposite, distally unilateral; rhizome conspicuous, filamentous; rhizoids unbranched, terminating in attachment pad.

Main axis erect, filament cells 50-115 µm diam., 300-375 µm long, walls 5-40 µm thick, distally tapering to 12-20 µm diam.; rhizome cells 50-130 µm diam., 130-400 µm long, walls 13-50 µm thick, uncorticated throughout; tetrasporangia solitary or in groups of 2-5 near joint, 60-80 µm diam., on unicellular stalk; spermatangial clusters oval to spherical, 26-40 µm diam., 40-80 µm long; cystocarp solitary or in small groups, hemispherical, 80-150 µm diam.

Fracture zone specimens: Seagrass bed of central fracture, 3 m deep, epiphytic on larger algae or *Thalassia testudinum*, 16.ii.1993, *D&M Littler 25041* (US). Seagrass bed of west fracture, 3 m deep, epiphytic on larger algae or *Thalassia testudinum*, 20.ii.1993, *D&M Littler 25149* (US). Bottom of east fracture, 7 m deep, epiphytic on larger algae or *Thalassia testudinum*, 16.ii.1993, *D&M Littler 25126* (US).



1. Main axis with branchlets somewhat radially arranged. 2. Cross section of main branch. 3. Branchlet with tetraspores forming at joints and branchlet apex.

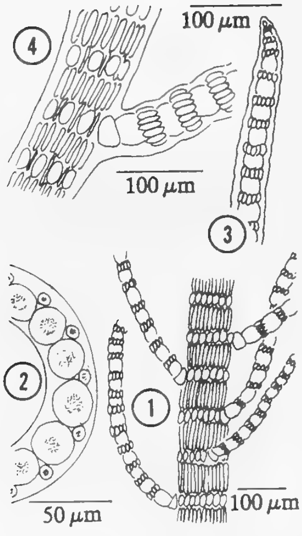
Spyridia filamentosa (Wulfen) Harvey 1833: 337.

Fucus filamentosus Wulfen 1803: 64.

Thallus filamentous, fuzzy, bush-like; to 20 cm tall; dull, pale pink; branching alternate; branchlets numerous, delicate, deciduous, unbranched, banded; holdfast small, disc-like.

Main axis 1-2 mm diam., central cell large, in single chain; surface cells in 1 layer, alternating zones of long narrow cells (6-10 µm diam., 50-70 µm long) and short wide cells (15-20 µm diam., 30-40 µm long; half as long, twice as wide); zones becoming obscure with age; branchlets radial, highly variable, 20-45 µm diam., 0.5-1.5 mm long; branchlet segments 40-100 µm long, uncorticated, apex pointed, spine-like; branchlet joints corticated; tetrasporangia spherical, sessile, 40-70 µm diam. at branchlet joint; spermatangia to 5 µm diam., blanketing lower third of branchlet; cystocarps terminal on short branches.

Fracture zone specimens: Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25045* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25006* (US).



1. Main axis with radial branchlets. 2. Cross section. 3. Branchlet apex. 4. Axis with branch showing corticating cell arrangement.

Spyridia hypnoides (Bory) Papenfuss 1968: 281.

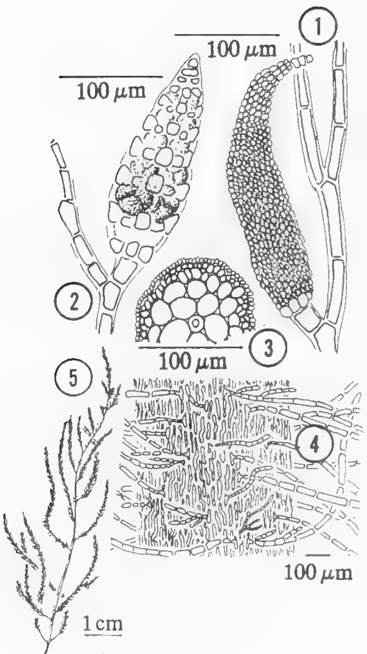
Thamnophora hypnoides Bory de Saint-Vincent 1834: 175.

Thallus fuzzy, filamentous, densely bushy; to 25 cm tall; rose-red; branching alternate in all directions; branch apices often hooked; branchlets numerous, delicate, deciduous, banded, radially arranged; holdfast small, inconspicuous.

Main axis 1-2 mm diam., central cells large, in single chain; surface cells small, initially alternating between long narrow cells and short wide cells, eventually in several layers; branchlets 30-50 µm diam., 0.3-2.0 mm long; branchlet segment 40-100 µm long, uncorticated; branchlet joints corticated, cells initially elongated, eventually splitting transversely to form smaller cells; apex pointed, occasionally with recurved spine; sporangia spherical, sessile, 50-85 µm diam., at joints, solitary or 2-5 in clusters; spermatangia expanding from joints; carposporophytes terminal on short branches surrounded by incurved filaments.

Fracture zone specimen: Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25174* (US).

Dasyaceae, Ceramiales



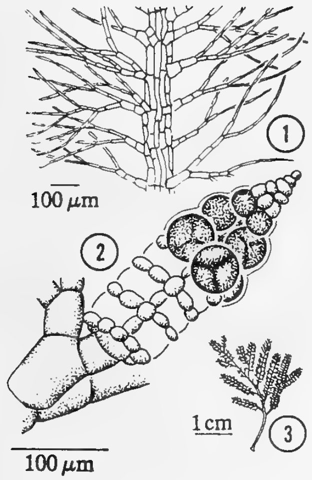
1. Spermatangial stichidium. 2. Tetrasporangial stichidium. 3. Cross section of branch. 4. Main axis with lateral branchlets. 5. Habit of plant.

**Dasya baillouviana* (Gmelin) Montagne 1841 [1839-1842]: 165.
Fucus baillouviana Gmelin 1768: 165.

Thallus erect or undulating, delicate, fluffy, soft; to 90 cm tall; bright-red to rose; branching alternate, generally sparse; branches slippery, slimy, long, graceful, densely covered by fine branchlets, base often denuded; holdfast small, inconspicuous, disc-like.

Main branches 2-3(-6) mm diam., corticated; branchlets filamentous, 2-7(-14) mm long, 3 times dichotomous, basal cells 10-40 µm diam., 20-50 µm long, tapering distally, apical cells 5-12 µm diam., to 200 µm long; tetrasporic plants sparser, paler; tetrasporangial stichidia (specialized reproductive branch) lance shaped, 80-160 µm diam., 0.60-1.25 mm long; tetrasporangia spherical, 40-80 µm diam.; spermatangial plants dense, deep red; spermatangial stichidia also lance shaped, 60-75 µm diam., 200-600 µm long; cystocarps single, occasionally 2-3, near tip of branchlets, urn shaped, 1.1 mm diam., neck 100-200 µm diam.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25083* (US), *D&M Littler 25085* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25019* (US), *D&M Littler 29031* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25127* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25192* (US).



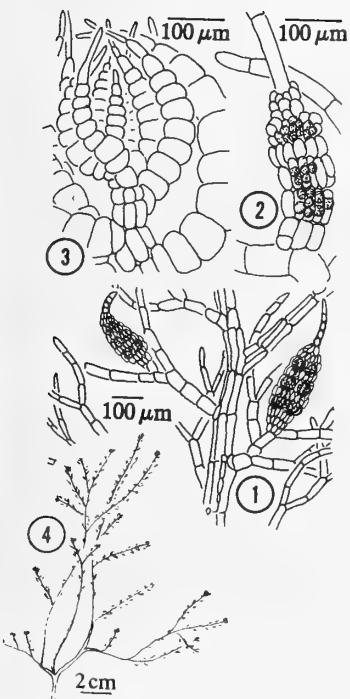
1. Axis with spirally arranged branchlets. 2. Tetrasporangial stichidium. 3. Habit of plant.

******Dasya mollis*** Harvey 1853: 62.

Thallus delicate, fine, bush-like; to 4(-15) cm tall; pale rose; branching irregular, no main axis apparent; branchlets filamentous, covering all branches; holdfast inconspicuous, disc-like.

Branches 1 mm diam., tapering distally, corticated; branchlets slender, limp, to 1 mm long, dichotomously dividing, whorled at close intervals, whorls obscured with age; branchlet cells 50 μm diam., 60 μm long at base, tapering to 6 μm diam., 90 μm long; tetrasporangial stichidia 135 μm diam., to 300 μm long, near base of branchlet; tetraspores spherical, to 50 μm diam.

Fracture zone specimen: Seagrass bed of central fracture, 3 m deep on shell fragment, 16.ii.1993, *D&M Littler 25034* (US).



1. Axis with tetrasporangial stichidium. 2. Spermatangial stichidium. 3. Apex with short swollen cells. 4. Habit of plant.

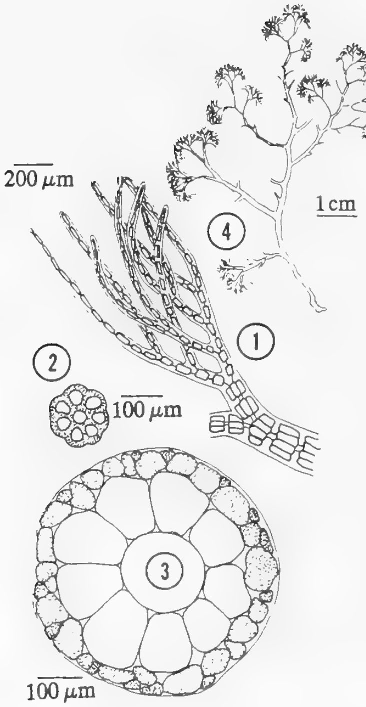
Dasya rigidula (Kützing) Ardissone 1878: 140.

Eupogonium rigidulum Kützing 1843: 415.

Thallus delicate, fluffy, soft; 1-2(-8) cm tall; rose to purple-red; branching irregular, generally sparse; branchlets spirally arranged, to 5 mm long, branching dichotomous, distally incurved, densely tufted at branch apex; holdfast small, inconspicuous, fibrous, secondarily attached by adventitious rhizoids.

Main axis 300-500 μm diam., uncorticated, occasionally corticated proximally or as small strands at branch base; branchlets uncorticated, basal cells to 140 μm diam., 1 diameter long, tapering distally, apical cells 10 μm diam., 10 diameters long, apices sharply pointed; tetrasporangial stichidia forming at lower branchlets, 120-170 μm diam., to 400 mm long, often with long terminal point, sessile or on 1-3 celled stalk; tetrasporangia spherical, 20-50 μm diam.; spermatangial stichidia similar in shape and position, to 100 μm diam., 300 μm long.

Fracture zone specimen: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25148* (US).



1. Branchlet with ultimate filamentous apices. 2. Cross section of branchlet. 3. Cross section of main axis. 4. Habit of plant.

****Heterosiphonia gibbesii*** (Harvey) Falkenberg 1901: 653.

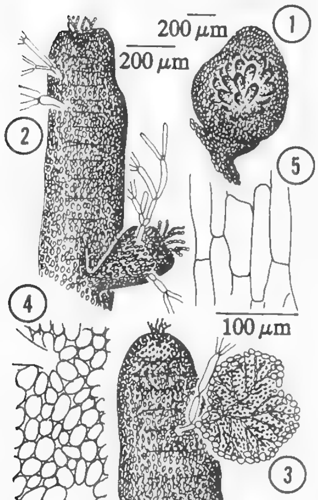
Dasya gibbesii Harvey 1853: 59, pl. XV, A.

Thallus soft, fluffy; to 20 cm tall; bright pink-red; lower branching sparse, alternate; branchlets absent near base, dense above, dichotomously divided, apices delicate, minute; holdfast small, disc-like.

Main axis to 1.5 mm diam., of 6-9 or more pericentral cells; corticated on older axes; branchlets tapering, of 6 pericentral cells, uncorticated; ultimate branchlets single filaments, to 30 μm diam.; tetrasporangial stichidia lance shaped, replacing lower branchlets; spermatangial stichidia similar, pointed; carpogonium near base of branchlets.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25101* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25023* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25144* (US).

Rhodomelaceae, Ceramiales



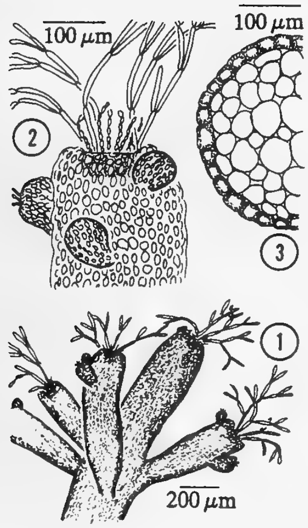
1. Cystocarp. 2. Branch apex. 3. Branch apex with spermatangial sori. 4. Immature surface cells with surface scars. 5. Elongated mature surface cells.

****Chondria collinsiana*** Howe 1920: 568.

Thallus soft, sparse, erect, solitary or gregarious; 1-3(-8) cm tall; straw-yellow to pink; main axis well-defined, cylindrical, 0.4-0.75 mm diam.; branching sparse, irregular; branchlets sparse, short, irregularly arranged, pinched at base, cone-shaped, unbranched; branchlet apices truncate to slightly rounded, tufted with fine, dichotomously branched filaments in terminal depression; holdfast small, disc-like.

Branchlets 250-450 μm diam., to 4.5 mm long; apical cell sunken in terminal depression; pericentral cells 5-6, large, rounded, ends thickened forming faint banding; surface cells 26-40 μm wide, 65-160 μm long, roundly rectangular, elongating with age, scar cells common on younger surfaces (resulting from deciduous apical filaments); tetrasporangia spherical, distal on outer branchlets; spermatangial sori disc shaped, circular to oval, to 500 μm diam., forming at base of apical filaments; cystocarps spherical to oval, to 700 μm diam., 800 μm long, on short stalk.

Fracture zone specimen: Seagrass bed of west fracture, 3 m deep, epiphytic on *Thalassia testudinum*, 20.ii.1993, *D&M Littler 25156* (US).



1. Branch apex. 2. Branchlet apex with tufted filaments arising from terminal depression. 3. Cross section of axis.

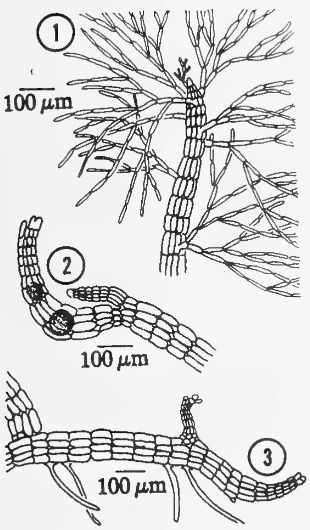
**Chondria dasyphylla* (Woodward) C. Agardh 1817: xviii.

Fucus dasyphyllus Woodward 1794: 239: pl. 23, figs. 1-3.

Thallus soft, sparsely bushy; 5-10(-30) cm tall; light yellow-brown to dark rose-red; main branching irregular; branches cylindrical, 1.0-1.5 mm diam. proximally, thinner distally; branchlets numerous, short, alternate, opposite or spirally arranged, constricted at base, cone shaped, unbranched; apices tufted with fine dichotomously branched filaments in terminal depression; holdfast small, disc-like.

Branchlets cylindrical, 200-600 µm diam, to 2-3(-10) mm long; apical cell sunken in terminal depression; pericentral cells 4-6, large, rounded; surface cells small, rounded; tetrasporangia spherical, 40-170 µm diam., near branchlet apices; spermatangial sori oval, 400-600 µm diam., developed on basal cell of apical filaments; cystocarps spherical to oval, to 1 mm diam., 700 µm long, near branchlet apices.

Fracture zone specimen: Seagrass bed of west fracture, 3 m deep, epiphytic on *Thalassia testudinum*, 20.ii.1993, *D&M Littler 25157* (US).



1. Branch apex with dichotomously branched filaments. 2. Tetrasporic branch. 3. Prostrate filament.

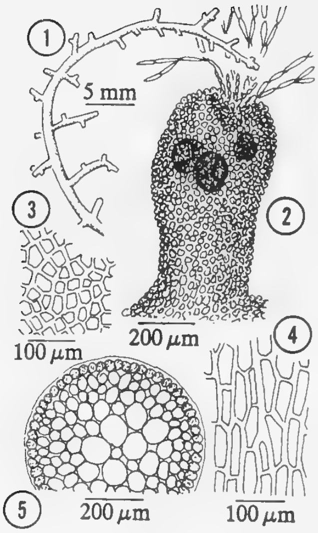
Herposiphonia secunda (C. Agardh) Ambronn 1880: 197.

Hutchinsia secunda C. Agardh 1824: 149.

Thallus prostrate, entangled, finely fibrous mats tightly adhering to substratum; of indeterminate size; red-brown when subtidal, yellow-brown when intertidal; prostrate branching irregularly alternate, apices upcurved; branchlets short, inconspicuous, unbranched; apex tufted; rhizoids single (seldom 2-3) celled, occasionally with finger-like, branched apices.

Prostrate axes 75-150 µm diam., of 7-9 pericentral cells, bearing single upright every 5-6 joints; erect branchlets 60-125 µm diam., 1-2 mm tall, segments as long, 4-9 pericentral cells, unbranched; apical filaments deciduous, dichotomously branched; tetraspores uniseriate (straight series) near branch apex, to 75 µm diam.; pericarps near branchlet apex, solitary.

Fracture zone specimen: Seagrass bed of central fracture, 3 m deep, epiphytic on larger algae or seagrass, 16.ii.1993, *D&M Littler 25038* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25081* (US).



1. Habit of plant. 2. Branchlet apex with tufted filaments arising from terminal depression. 3. Immature surface cells. 4. Elongated mature surface cells. 5. Cross section of main axis.

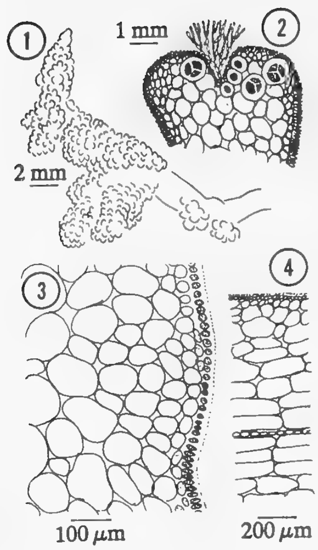
Laurencia implicata J. Agardh 1852 [1852-1863]: 745.

Conspecific with *Laurencia intricata* Lamouroux 1813: 131, plate 9 (figures 8 and 9) - see Silva et al. 1987: 66.

Thallus fleshy, gregarious, in loose mats or solitary; 5-10(-25) cm tall; yellow-green, stubby branchlets often rose; branching sparse, irregularly alternate; branchlets 0.5-0.75 mm diam., cylindrical, rarely club shaped, irregularly alternate, occasionally opposite; apices tufted; holdfast fibrous.

Apical cell sunken in terminal depression; pericentral cells 4, occasionally to 6; branch central cells large, colorless, thin walled, decreasing in size toward surface; surface cells deeply pigmented, 40-50 µm diam., to 70 µm long; apices tufted with inconspicuous, fine, dichotomously branched filaments in terminal depression; tetrasporangia just below apices of branchlet, beneath surface cells, forming minute raised areas; spermatangial clusters in apical depression, small, oval, or barrel shaped; pericarps (envelope surrounding cystocarp) partly embedded.

Fracture zone specimen: Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25033* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25150* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25172* (US).



1. Habit of plant. 2. Branchlet apex with tuft of dichotomously divided filaments in apical depression. 3. Cross section - main axis. 4. Longitudinal section - main axis.

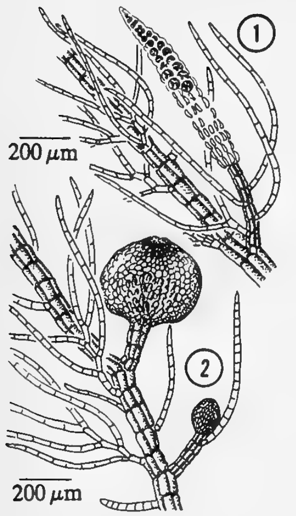
Laurencia papillosa (C. Agardh) Greville 1830: lii.

Chondria papillosa C. Agardh 1822a: 344.

Thallus gregarious or solitary, cartilaginous; 5-8(-16) cm tall; green or purple-green; branching alternate or irregular; proximal branches 1-2 mm diam., devoid of branchlets; distal branches densely covered with short, tough, knobby, club-shaped branchlets; apices tufted; holdfast fibrous, disc-like.

Branch central cells large, colorless, decreasing in size toward surface; surface cells one layer, small, deeply pigmented, thick-walled, 27 µm diam., 30 µm long in main axis, 8-15 µm wide, 30 µm long in lateral branchlets; apices tufted with inconspicuous, fine, dichotomously branched filaments in terminal depression; tetrasporangia in irregular lobed branchlets just below apices, beneath surface cells; spermatangial clusters in apical depression, small, oval, or barrel shaped; cystocarps partly immersed.

Fracture zone specimen: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25088* (US).



1. Axial branch with tetrasporangial stichidium. 2. Axial branch with cystocarp.

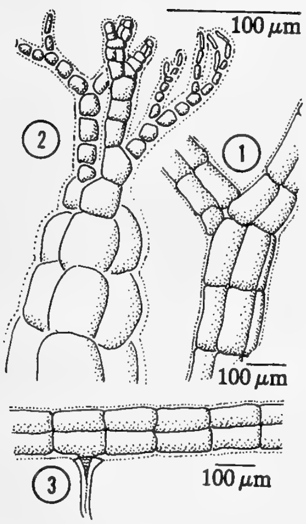
Murrayella periclados (C. Agardh) Schmitz 1893: 227.

Hutchinsia periclados C. Agardh 1828: 101.

Thallus dense, erect, turf-like; to 5 cm tall; dull, dark red-brown; branching dichotomous below, alternate above; branchlets deciduous, fine, slightly upcurved, unbranched or branched oppositely alternate; rhizome slender, creeping; rhizoids fine, filamentous.

Branches of 4 pericentral cells, uncorticated; branchlets initially at each joint, monosiphonous; branchlet cells 28 µm diam, 60 µm long; tetrasporangial stichidia to 105 µm diam., 900 µm long, terminal on short polysiphonous branch, unbranched or possessing monosiphonous branchlets; tetrasporangia 4 per whorl, to 55 µm diam.; cystocarps spherical to oval, to 400 µm diam., terminal on short polysiphonous branch.

Fracture zone specimen: Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25035* (US).



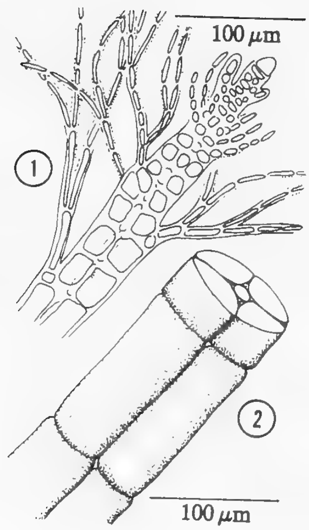
1. Filament branch. 2. Filament apex. 3. Prostrate filament - note rhizoid separated by cell wall.

Polysiphonia ferulacea Suhr in J. Agardh 1863 [1851-1863]: 980.

Thallus filamentous, fine, tufted, bushy; to 6(-15) cm tall; light brown to purple-red; main branching alternate; initially attached by small disc, later by numerous unicellular rhizoids.

Main branches 80-100(-300) µm diam.; secondary branches slightly thinner, often basally constricted, of 4 pericentral cells, uncorticated, filament scar cells common; segments one diameter long or less; apical filaments highly branched, eventually deciduous, abundant, on every 4th-6th segment, immature often sickle-shaped; rhizoids separated by cell wall, distal on pericentral cells; tetrasporangia spherical, 50-60 µm diam., in swollen spiral series on outer branchlets; spermatangial branchlets lateral on lower segment of apical filaments, cylindrical, 60 µm diam., 150-500 µm long, characteristically with 1-2 sterile, conspicuous, thick-walled cells at apex; cystocarps spherical to oval, 200 µm diam.

Fracture zone specimens: Seagrass bed of central fracture, 3 m deep, epiphytic on larger algae or seagrass, 16.ii.1993, *D&M Littler 25026 (US), D&M Littler 25042* (US).



1. Filament apex. 2. Cross section of filament showing 4 pericentral cells surrounding central filament.

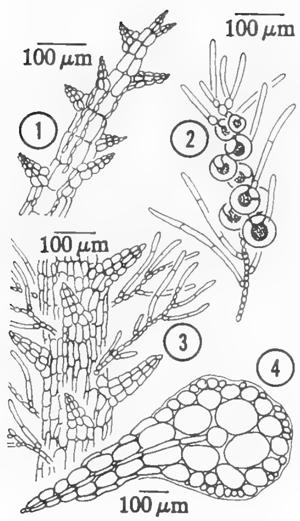
Polysiphonia scopulorum* var. *villum (J. Agardh) Hollenberg 1968: 81, fig. 7a.

Polysiphonia villum J. Agardh 1863 [1851-1863]: 941.

Thallus filamentous, fine, tufted; to 3 cm tall; light brown-red; main branching alternate; attached by numerous unicellular rhizoids descending from prostrate branches.

Main branches 40-80 μm diam.; secondary branches slightly thinner, of 4 pericentral cells, uncorticated; filament scar cells generally lacking; segments to 2 diameters long; apical filaments deciduous, alternate on every 2-6 segments; prostrate runner 60-100 μm diam.; rhizoids from center of pericentral cell, in open connection; tetrasporangia spherical, 50-60 μm diam., in swollen straight series just below branch apices, in straight series; spermatangial branchlets forming from filaments, cylindrical; cystocarps oval, 150-190 μm diam.

Fracture zone specimens: Seagrass bed of central fracture, 3 m deep, epiphytic on seagrass, 16.ii.1993, *D&M Littler 25044* (US). Seagrass bed of west fracture, 3 m deep, epiphytic on seagrass, 20.ii.1993, *D&M Littler 25155* (US).



1. Apex. 2. Tetrasporangia spirally arranged on surface filament. 3. Main axis with numerous spines, lateral, alternately branched, surface filaments. 4. Cross section - main axis.

Wrightiella blodgettii (Harvey) Schmitz 1893: 221.

Alsidium blodgettii Harvey 1853: 16, pl. XV, B.

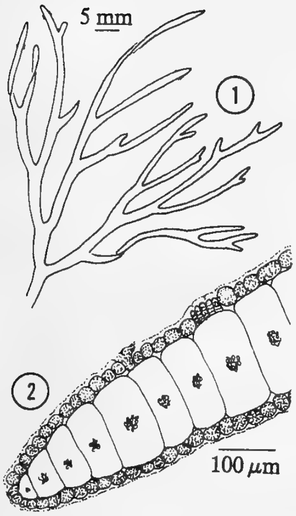
Thallus erect, stiff, spiny; to 20 cm tall; bright red to pink; primary branching proximal, irregular; spines numerous above, absent below, 1-5 mm long, spur-like, solitary or in pairs, occasionally forked, tapered at apex; surface filaments sparse; holdfast small, inconspicuous, disc-like or tap-root-like in soft sediment.

Branches 0.5-1.3 mm diam., 4-5 pericentral cells, partially or completely corticated, with numerous short spines and fine filaments; spines to 350 μm diam., spiral, in 4 vertical rows; filaments monosiphonous, to 30 μm diam., 1 mm long, deciduous, branching irregularly spiral, basal cell of ultimate branchlet uniquely small; tetrasporangia spherical, 30-60 μm diam., in spiral series on main branch of filaments; cystocarps oval or urn shaped, on short stalks.

Fracture zone specimens: Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25132* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25016* (US).

PHAEOPHYTA

Dictyotaceae, Dictyotales



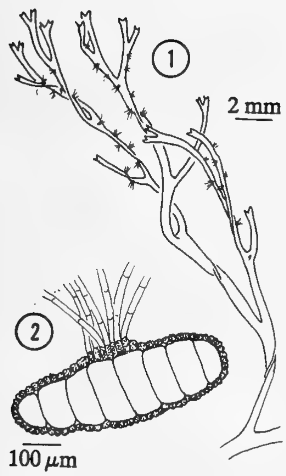
1. Habit of blades showing cervicorn branching pattern. 2. Cross section.

Dictyota cervicornis Kützing 1859: 11, pl. 24, fig. 2.

Thallus bushy; to 20 cm tall; olive-brown; branching dichotomously asymmetrical (cervicorn - one branch terminating development); branches 1-2.5 mm wide, often twisted or spiral, apices pointed; holdfast small, fibrous, mat-like.

Blades 180-360 μm thick, 10-25 medulla cells wide; medulla cells in 1 layer, rectangular, arranged in rows; surface cells in 1 layer, 30-40 μm diam., 3-5 transversing each medulla cell; surface filaments in tufts, more numerous at margins than central axis, soon deciduous.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25097* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25146* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25055* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25119* (US).



1. Habit of blades. 2. Cross section with large medullary cells, small surface cells and centered filament cluster.

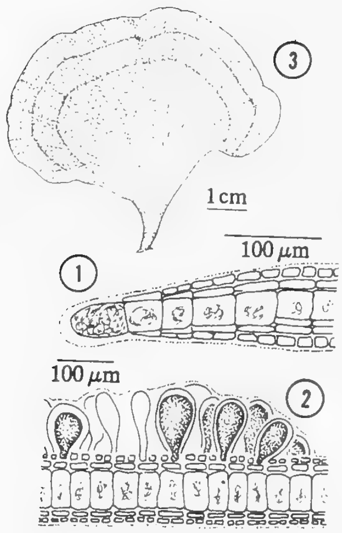
Dictyota linearis (C. Agardh) Greville 1830: xliii.

Zonaria linearis C. Agardh 1820: 134.

Thallus bushy, in entangled clumps; to 12 cm tall; brown; branching dichotomous, occasionally irregular; branches of uniform width, 0.5-1.5 mm throughout, often twisted, apices pointed; holdfast small, fibrous, mat-like.

Blades 200-360 μm thick, 6-20 medulla cells wide; medulla cells in 1 layer, rectangular, arranged in rows; surface cells in 1 layer, 30-40 μm diam., in regular rows, 3-5 transversing each medulla cell; surface filaments tufted, aligned down central axis, often persistent; sporangia solitary, scattered, generally near blade margins.

Fracture zone specimens: Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25030* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25147* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25013* (US).



1. Cross section - blade growing margin. 2. Cross section - reproductive structures on blade surface. 3. Habit of plant.

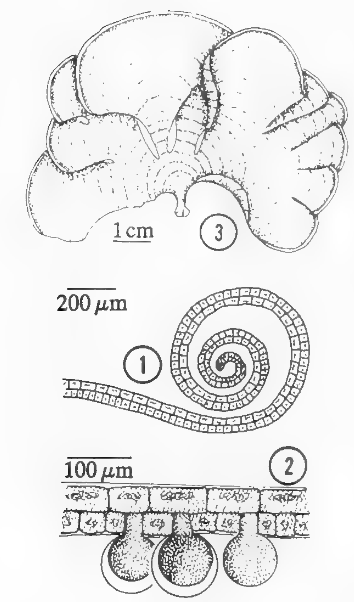
Lobophora variegata (Lamouroux) Womersley 1967: 221.

Dictyota variegata Lamouroux 1809: 331.

Thallus prostrate as crusts, in shelf-like layers, or erect in ruffled clusters; 15 cm diam.; light brown; blades thin, overlapping or fan shaped; rhizoids basal or on lower surface in prostrate forms, tan to olive brown.

Blades 100-300 µm thick; medulla cells in 1 layer, large; subsurface cells in 1-2 layers, mid-sized; surface cells in 1 layer, small, darkly pigmented; growth originates from marginal cells; reproductive structures scattered over upper and lower surfaces.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25086* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25060* (US). Wall of central fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25051* (US). Wall of west fracture, 4 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25170* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25187* (US).



1. Cross section - incurved growing margin. 2. Cross section - 2 layered thallus with sporangia. 3. Habit of plant.

Padina sanctae-crucis Bøgesen 1914: 201, fig. 153, 154.

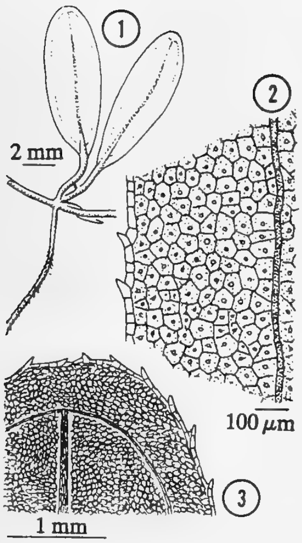
Thallus leaf-like clusters, ruffled; to 15 cm tall; brown, upper surface chalky white alternating with light yellow-brown bands, lower surface less calcified with darker brown bands; blades fan shaped, to 9 cm broad, concentrically zoned, substantially calcified, margins in-rolled; rhizoidal base matted.

Blades to 90(-150) µm thick, of 2 cell layers; dorsal cells rectangular, 30-60 µm wide; ventral cells smaller, rectangular, 24-35 µm wide; hair-like filaments 15-25 µm diam., in concentric zones; reproductive structures above every second filament band on both surfaces; sporangia to 120 µm diam., forming irregular bands; oögonia 30-50 µm diam. in 1-2 bands; antheridia in broken bands.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25087* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25043* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25135* (US). Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25066* (US).

MAGNOLIOPHYTA

Hydrocharitaceae, Butomales



1. Habit of plant. 2. Marginal teeth. 3. Leaf apex with marginal veins meeting center vein.

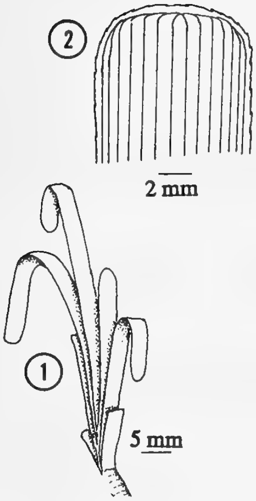
Halophila decipiens Ostenfeld 1902: 260, with fig.

Plants delicate, small, in leafy patches; to 1 m in diam.; bright green; stem slender, 3-15 mm long; leaves to 3 mm wide, 3-6 mm long, oval, one pair per node; leaf margin with extremely fine teeth; rhizome extensive; major root descending below each pair of leaves, soon covered by fine rootlets.

Leaves with central vein of rectangular cells; margin veins splitting from central vein at leaf base, paralleling margin, meeting central vein again just below leaf apex; rhizome 0.5-1.0 mm diam.; roots 0.2-0.5 mm diam.; rootlets colorless, 10-20 μm diam.

Fracture zone specimens: Wall of east fracture, 4 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25080* (US). Bottom of east fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25111* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25004* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25180* (US).

Hydrocharitaceae, Butomales



1. Habit of plant. 2. Blade apex with parallel veins.

Thalassia testudinum Banks in König 1805: 96.

Plants erect, coarse, grass-like; grass-green; leaves strap shaped, 4-12 mm wide, 10-60 cm tall; rhizomes extensive, creeping, stoloniferous, 3-6 mm diam.; roots fine, fibrous, abundant.

Leaves having 9-15 parallel veins, connected by perpendicular cross veins at approximately 1 mm intervals; margins smooth, distally with minute spines.

Fracture zone specimens: Seagrass bed of east fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25105* (US). Seagrass bed of central fracture, 3 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25018* (US). Seagrass bed of west fracture, 3 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25128* (US). Bottom of central fracture, 7 m deep on mangrove peat, 16.ii.1993, *D&M Littler 25000* (US). Bottom of west fracture, 7 m deep on mangrove peat, 20.ii.1993, *D&M Littler 25181* (US).

DISCUSSION

This study documents the predominant flora of a previously unrecognized fractured mangrove-peat ecosystem. There is little variation from fracture to fracture except as a function of the age (size) of a given fracture. As fractures develop, they become larger and more exposed to light penetration allowing a sparse flora to become established. The unique habitats of the fractured peat zone of Tobacco Range support an interesting but reduced flora of 61 macroalgae and 2 vascular plants (Table 1). The algae consist of 35 Chlorophyta, 22 Rhodophyta, and 4 Phaeophyta. Fourteen of these represent new records for Belize and, in conjunction with the 16 Chlorophyta recently added by Littler & Littler (1990, 1991, 1992), and 7 Rhodophyta added by Kapraun & Norris (1982) bring the marine plant total to 284 taxa.

The peat fractures contain 23 taxa (18 Chlorophyta, 4 Rhodophyta, 1 Magnoliophyta) that were not present in the adjacent seagrass beds (Table 1); the latter contain 15 taxa (12 Rhodophyta, 3 Chlorophyta) that were not present in the fracture habitats. Of the 12 species common to both the fracture habitats and the adjacent seagrass beds, 9 were Chlorophyta, 2 Phaeophyta, and 1 Rhodophyta. The fracture bottoms contained 8 species not found on the vertical walls (*Caulerpa racemosa, C. sertularioides, Halimeda incrassata, Penicillus capitatus, P. pyriformis, Udotea caribaea, U. flabellum, U. wilsonii*), whereas the latter supported 6 species (*Caulerpa paspaloides* var. *phleoides, Cladophoropsis membranacea, Rhipiliopsis stri, Siphonocladus rigidus, Valoniopsis pachynema, Centroceras clavulatum*) not found elsewhere in the fracture zone.

The eight Chlorophyta unique to the fracture bottoms are relatively slow-growing psammophytic rhizophytes (sensu Raven 1981) with rhizoidal systems anchoring them to the silty decomposed peat substratum. Only certain rhizophytes appear capable of attaching to this extremely soft sedimentary medium which consists mainly of the fractured peat blocks that have collapsed and aerobically decomposed. Dominants on the bottoms include *Halimeda simulans, H. incrassata, Penicillus capitatus, Udotea cyathiformis, U. flabellum, U. caribaea, U. wilsonii, Caulerpa paspaloides, C. sertularioides, C. mexicana*, and the seagrass, *Halophila decipiens*. We have not found *U. caribaea* elsewhere in Belize.

The most interesting dominant of the fracture wall habitat is *Rhipiliopsis stri*, an otherwise rare alga. *Caulerpa verticillata*, a common alga on mangrove roots, is quite abundant on fracture walls, but also spreads laterally over the silty fracture bottoms. *Lobophora variegata* forms unusually large shelf-like thalli on the walls, similar to those we have observed on vertical, calcareous, wall-like reef habitats and on mangrove roots.

The adjacent *Thalassia testudinum* beds are characteristic of other seagrass communities, even though the substratum is fossil peat in this case. The dominant plants are *T. testudinum, Lobophora variegata*, and various species of *Halimeda* and *Caulerpa*. The *Thalassia* blades provide attachment sites for numerous epiphytes (mostly Rhodophyta), thereby greatly increasing the biodiversity of this algal group relative to the two disturbed fracture habitats. Because overall macroalgal cover on the mostly barren bottom and wall habitats is conspicuously lower than on the surrounding seagrass habitat and the dominant plants within fractures are calcareous forms documented (Littler et al., 1983) to be relatively slow growing, this lower community biodiversity and productivity is posited as a result of the fracturing process.

ACKNOWLEDGEMENTS

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Table 1. Macrophytes occurring in eastern (E), central (C), and western (W) fractures within the three major habitat types of the Tobacco Range Fracture Zone. Species indicated by asterisks indicate records new to Belize.

Phyla and Species	Habitat Types: Seagrass Beds	Habitat Types: Vertical Walls	Habitat Types: Fracture Bottoms
Chlorophyta			
Acetabularia crenulata	E C W	C W	E C W
Anadyomene stellata	C W	E C W	
Avrainvillea nigricans	E W	E C W	W
Caulerpa cupressoides		E	E C W
Caulerpa mexicana		E W	W
Caulerpa microphysa		E W	E C W
**Caulerpa paspaloides* var. *phleoides*		E	
**Caulerpa paspaloides* var. *wurdemanni*	E C W	W	E C
Caulerpa racemosa			E
Caulerpa sertularioides			E
Caulerpa verticillata		E C	E C
**Cladophora albida*		E	C
Cladophoropsis membranacea		W	
**Dasycladus vermicularis*	E C W		
Dictyosphaeria cavernosa	E C W		
Halimeda incrassata			W
Halimeda monile	E C		C W
Halimeda simulans	C W		E C W
Neomeris annulata	W		
Penicillus capitatus			E C W
Penicillus lamourouxii	W	E C	C
Penicillus pyriformis			W
**Rhipiliopsis stri*		E C W	
**Rhipocephalus oblongus*		E	E C
Rhipocephalus phoenix	E C W	E C W	E C
**Siphonocladus rigida*		W	
Udotea abbottiorum	E W	E W	E W
Udotea caribaea			E C W
Udotea cyathiformis	E C W	E C	E C W
Udotea flabellum			E C W
Udotea luna	E W	E	C
Udotea wilsonii			E
Valonia macrophysa	C W	C W	
Valoniopsis pachynema		C W	
Ventricaria ventricosa	W	E W	W

Table 1. Continued.

Phyla and Species	Habitat Types: Seagrass Beds	Vertical Walls	Fracture Bottoms
Rhodophyta			
**Acrothamnion butleriae*		C	E
Amphiroa fragilissima	E C W	E C W	E
Amphiroa rigida var. *antillana*	W		
Centroceras clavulatum		W	
Ceramium nitens	E		
**Chondria collinsiana*	W		
**Chondria dasyphylla*	W		
**Dasya baillouviana*	E C W		W
**Dasya mollis*	C		
Dasya rigidula	W		
Herposiphonia secunda	C	E	
**Heterosiphonia gibbesii*	E C W		
Laurencia intricata	C W	W	
Laurencia papillosa	E		
Murrayella periclados	C		
Callithamnion halliae	W		
Polysiphonia ferulacea	C		
Polysiphonia scopulorum var. *villum*	C W		
**Spermothamnion gymnocarpum*	C W		E
Spyridia filamentosa		C	C
Spyridia hypnoides		W	
Wrightiella blodgettii	W		C
Phaeophyta			
Dictyota linearis	C W		
Dictyota cervicornis	E W	C	E C
Lobophora variegata	E	E C W	W
Padina sanctae-crucis	E C W	E	
Magnoliophytae			
Halophila decipiens		E	E C W
Thalassia testudinum	E C W		C W

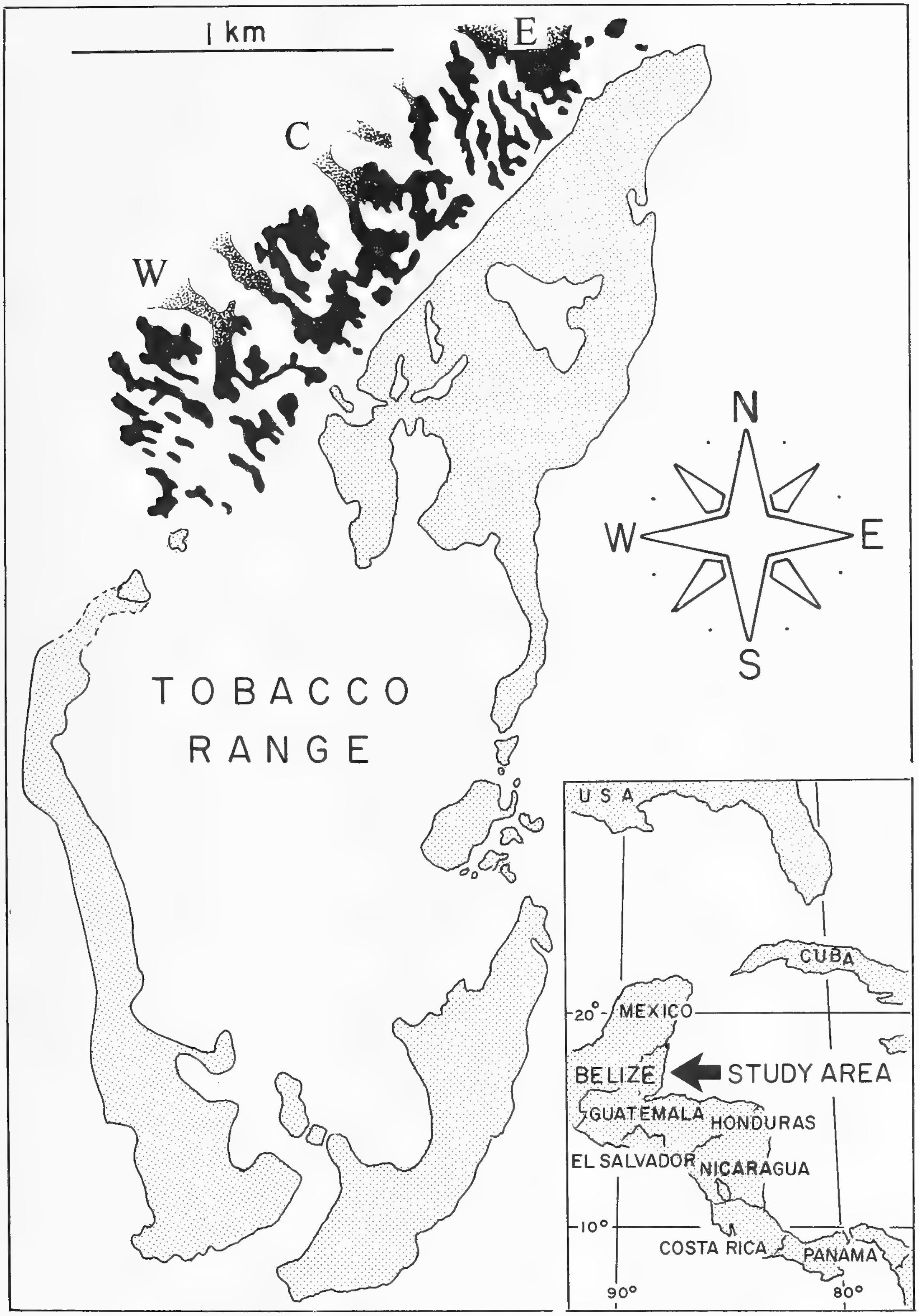

Figure 1. Map of Tobacco Range mangrove islands showing fractured peat area in black along the northwest shoreline of the north island. Fractures studied are labelled W = west, C = central, and E = east.

ATOLL RESEARCH BULLETIN

NO. 430

HOLOCENE HISTORY OF TOBACCO RANGE, BELIZE, CENTRAL AMERICA

BY

I.G. MACINTYRE, M.M. LITTLER, AND D.S. LITTLER

ISSUED BY
NATIONAL MUSEUM OF NATURAL HISTORY
SMITHSONIAN INSTITUTION
WASHINGTON, D.C., U.S.A.
AUGUST 1995

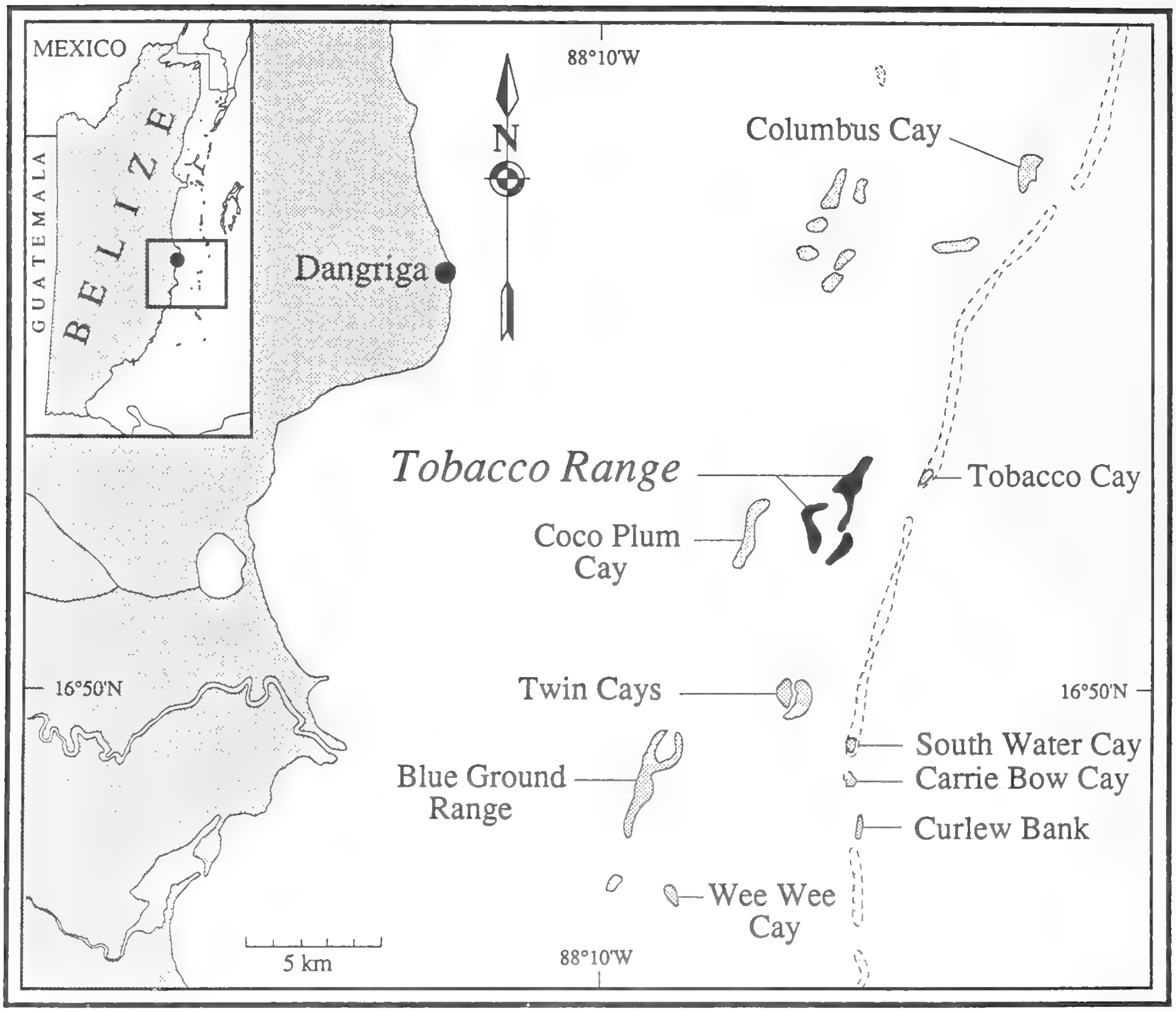

Figure 1. Index map showing the location of the Tobacco Range mangrove island complex on the outer platform of the Belizean Barrier Reef.

HOLOCENE HISTORY OF TOBACCO RANGE, BELIZE,CENTRAL AMERICA

BY

Ian G. Macintyre[1], Mark M. Littler[2], and Diane S. Littler[2]

ABSTRACT

Sediment-core samples from seven vibracores and ten soil-sampling probes across the northeastern island of Tobacco Range indicate that this mangrove complex has been a mangrove community throughout its entire Holocene history. Samples from cores and probes documented some of the thickest mangrove peat sections ever recorded, up to 10 m thick, with thin basal mud sections overlying the eroded Pleistocene limestone surface. This peat consists of upper sections of spongy, well-preserved "broad-fibered" peat with readily recognizable plant remains, which overlies a partially decomposed dense "fine-fibered" peat with almost no macroscopic plant fragments. The basal muds, which consist of a mixture of calcareous and non-carbonate sediments, are probably a reworked soil. Peat-forming mangrove communities became established on Pleistocene limestone areas of topographically high relief about 7,000 yrs B.P. and accumulated peat at rates of up to 4.3 m/1000 yrs, which allowed thèm to keep pace with the rising seas of the Holocene transgression. Vibracores off the west coast reveal thick sections of soft fine-fibered peat underlying more coherent broad-fibered peat. Undercutting has produced extensive fracturing and slumping of the peat deposits that has resulted in spectacular sea-floor relief. Radiocarbon dates of Tobacco Range peat samples confirm that the late Holocene history of sea-level rise reported for other western Atlantic areas is valid for Belize.

INTRODUCTION

Mangrove peat recovered in sediment cores from several studies (Purdy, 1974; Ebanks, 1975; Halley et al., 1977; Shinn et al., 1982) indicates that mangrove communities were established on the Belizean continental shelf soon after this shelf was flooded by the rising seas of the Holocene transgression. Most of these mangrove communities were eventually drowned and buried under calcareous marine sediments, except in areas of higher topographic relief on the underlying Pleistocene surface, where the mangrove communities survived to form some of the thickest Holocene peat sections ever recorded -- one such area is Tobacco Range (Fig.1).

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In this study we analyzed sediment cores to investigate the Holocene history of the Tobacco Range mangrove complex and to see how these thick peat accumulations relate to other reports of Holocene Belizean peat deposits. We were particularly interested in how radiocarbon dated samples from this and previous studies provide a better understanding of the late Holocene sea-level curve for the Belize area. In addition, we collected subsurface data in an attempt to explain the unique fracturing and slumping of submerged peat off the northwest coast of the Tobacco Range island complex.

METHODS

During March 1987, seven continuous sediment cores were collected using a vibracorer with aluminum pipes, each of which was 9 m long with a diameter of 7.6 cm and fitted with a core catcher. (Fig.1). Six of these cores were collected along a transect (oriented southeast to northwest) that bisects the northeastern and largest island of the Tobacco Range mangrove complex (Fig.2), five of which were collected from the west coast -- one on the island, one from the shallow-water unfractured peat surface, and three from deeper areas of slumped peat (Fig.3).

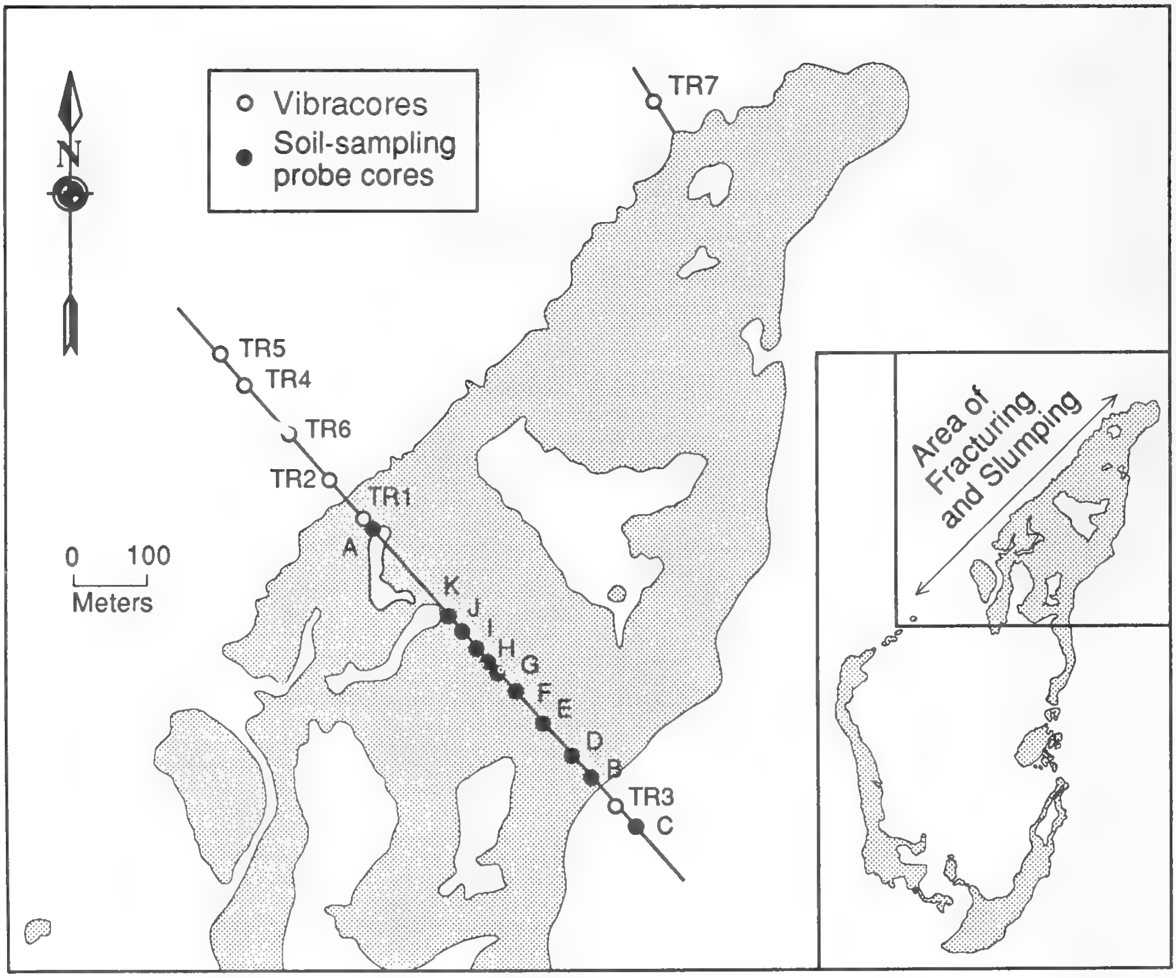

Figure 2. Map of the northeastern island of Tobacco Range with locations of vibracores and soil-sampling probe cores.

Figure 3. Vibracoring underwater in area of slumped peat off the west coast of Tobacco Range. Depth 7 m.

Figure 4. Vibracoring in shallow water off the east coast of Tobacco Range.

A single core was collected along the transect line off the shallow windward east coast (Fig.4). In addition, one core was collected close to the north point off the west coast of this island near fresh fractures in the *Thalassia*-covered submerged peat surface. The depth of penetration was recorded at each vibracore site and compared with the length of core recovered to establish a compaction correction that was applied to the peat sections in each core. Cores were left in the aluminium pipes and cut into 3 m sections that were capped and shipped for laboratory analyses.

To obtain a more complete record of peat accumulation along the study transect, we returned in March 1989 to collect short core samples at varying depths with Macaulay and Davis soil-sampling probes (Fig.5). A total of eleven sites were established on the study transect that extended our subsurface sampling across the entire island to a point 80 m off the east coast (Fig.2). These samples were described in the field and preserved in plastic bags for later analyses.

Figure 5. Collecting a peat sample from a Macaulay soil-sampling probe.

In the laboratory, carbonate and non-carbonate mineralogies were determined by standard power X-ray diffraction techniques using CuKα radiation (Chave,1954; Milliman, 1974). The mole% magnesium carbonate in calcites was calculated from d(211) spacings in relation to quantitative curves constructed by Goldsmith and Graft (1958).

Radiocarbon dates were determined by Beta Analytic Inc. using a Libby half-life of 5568 years and 95% of the activity of the National Bureau of Standards oxalic acid was used as the modern standard. Each sample was carefully examined under the microscope to remove rootlets that were noncontemporaneous with the peat being dated. All carbonate material was removed with an acid pretreatment. After thorough washings in distilled water, each sample was analyzed. No corrections were made for the DeVries effect, reservoir effect, or for natural isotopic fractionation.

RESULTS

Subsurface Facies

As can be seen from the data plotted on a cross-section along the transect (Fig.6), except for thin basal sections of terrigenous clay above the Pleistocene surface, almost the entire series of core intervals, both from the island and offshore, consisted of mangrove peat with a maximum thickness of 10 m.

This peat can be classified as two basic types: 1) The well-preserved "broad-fibered peat", which tended to be brown to reddish brown in color with a spongy texture of flattened coarse fibers, roots, and rootlets (Figs.6 and 7) "fine-fibered peat" that was usually dark brown to brownish black with a generally uniform pasty dense texture of fine fibers (Figs.6 and 8). This partially decomposed peat exhibited almost no identifiable plant remains in hand specimens and smeared readily between the fingers. All of this peat was probably derived from mangrove communities similar to those found on Tobacco Range today. A more detailed description of the composition and chemistry of these peat deposits is given by Cameron and Palmer (1995, this volume).

The only other significant facies in the sediment cores was the basal mud that was found on the erosional Pleistocene limestone surface. This basal mud was watery in some sections and highly variable in peat content, which was reflected in its color that varied from medium grey to grey brown. The carbonate content was also highly variable, ranging from 30% to 80%. Much of this carbonate is composed of lithic fragments derived from the underlying Pleistocene limestone. One large *Porites porites* coral fragment from the basal mud in TR 4 (Fig.9) was found in X-ray diffraction analysis to contain 14% calcite (<2 mole % $MgCO_3$), clearly indicating that this coral was subaerially exposed and therefore derived from the Pleistocene substrate. Along with this residual carbonate debris, there were also some Holocene skeletal grains, which were mostly marine molluscan and echinoid fragments.

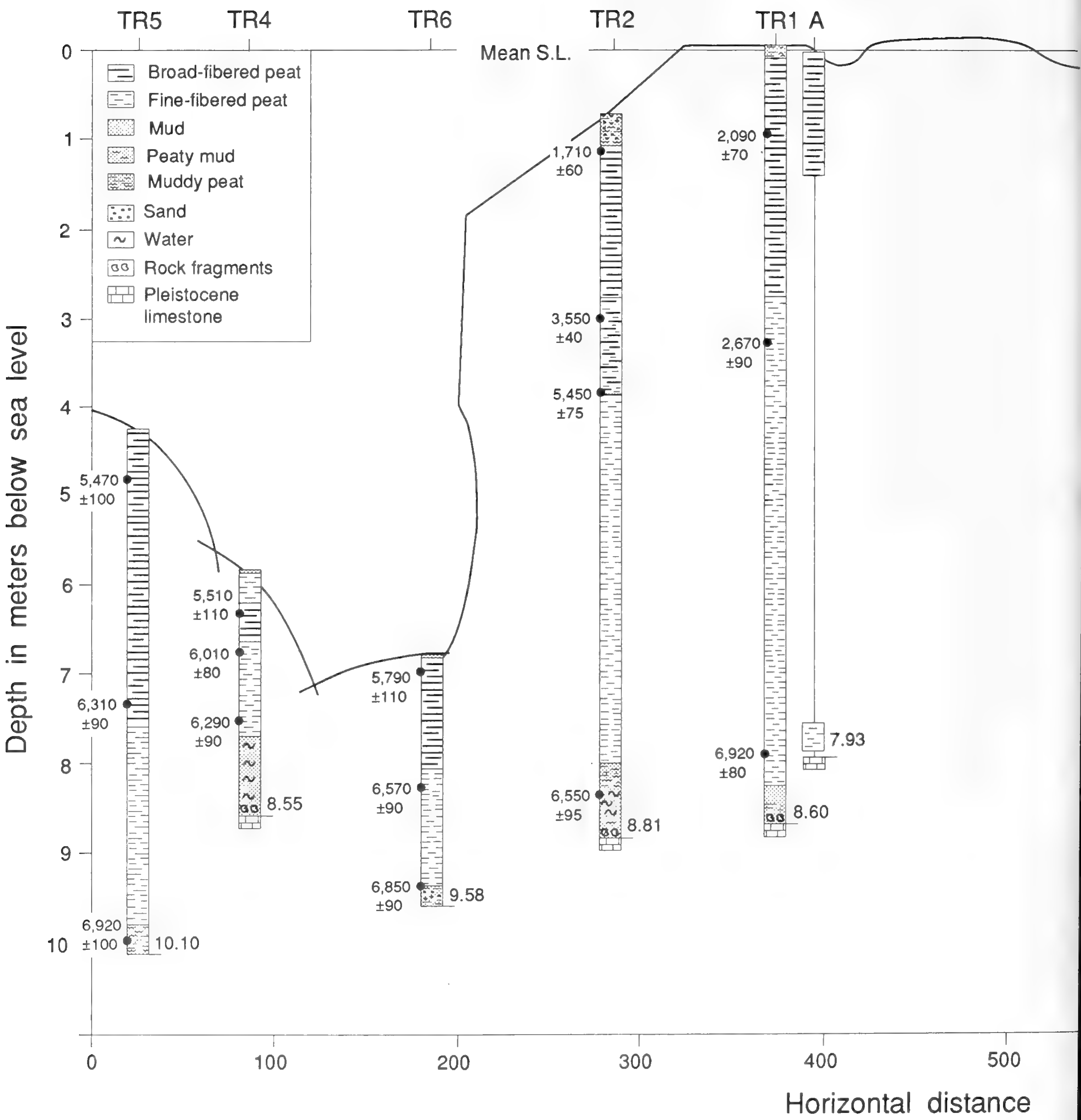

Figure 6. Cross section along the vibracore and soil-sampling core transect across northeastern island of Tobacco Range (see Fig.2). Subsurface distribution of peat and sediments is shown along with the locations of radiocarbon-dated peat. The total depth below mean sea level in meters is indicated at the base of each core log.

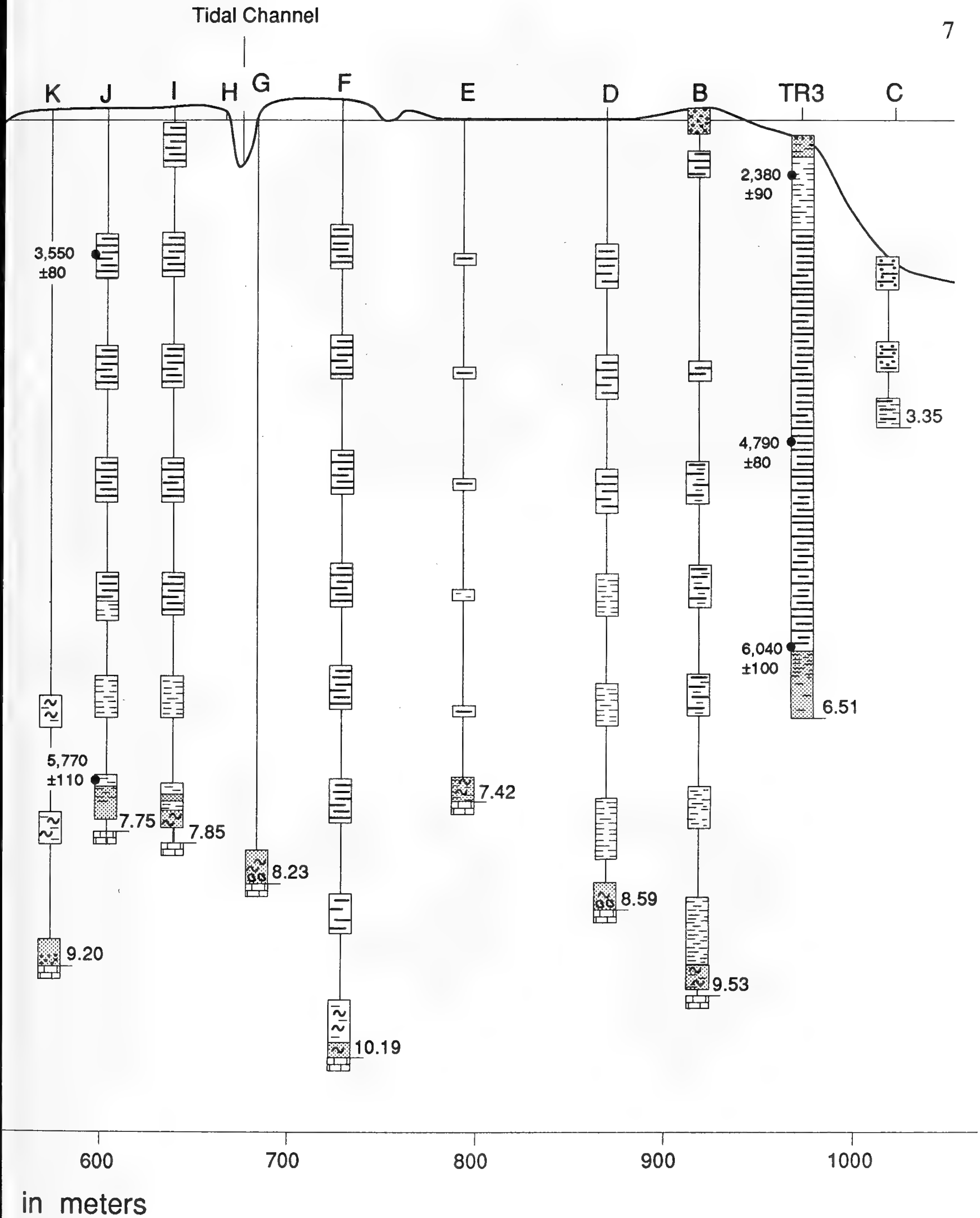
Tidal Channel
K
J
I
H
G
F
E
D
B
TR3
C
3,550 ±80
5,770 ±110
2,380 ±90
4,790 ±80
6,040 ±100
9.20
7.75
7.85
8.23
10.19
7.42
8.59
9.53
6.51
3.35
600
700
800
900
1000
in meters

Figure 7. Broad-fibered peat showing the open spongy texture of coarse flattened fibers and plant remains. Vibracore TR 1. Depth interval 11 to 23 cm below MSL.

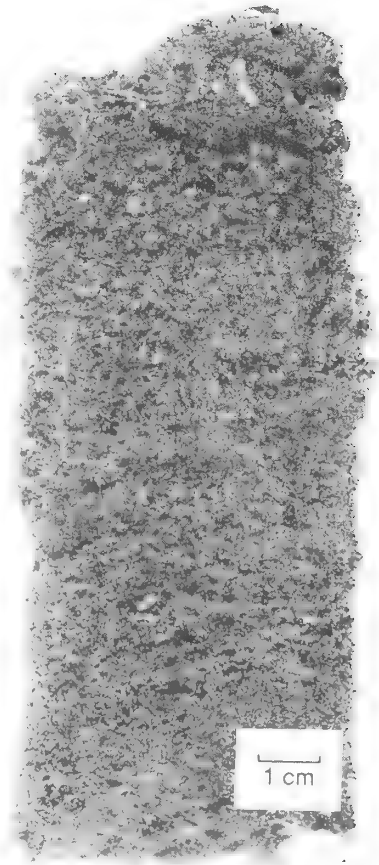

Figure 8. Fine-fibered peat with characteristic uniform and relatively dense texture with a lack of recognizable plant remains. Vibracore TR 1. Depth interval 5.98 to 6.13 m below MSL.

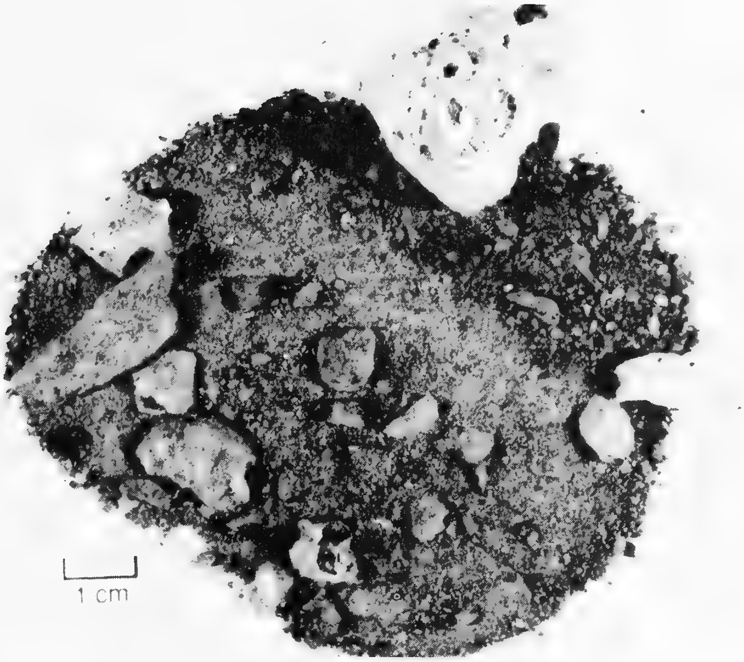

Figure 9. Basal mud sample from vibracore TR 4. Note rock fragments and gastropod. Large fragment is coral (*Porites porites*) that was eroded from underlying Pleistocene limestone. Depth interval 7.68 to 8.55 m below MSL.

One consistent feature of the basal mud was the presence of both quartz and kaolinite/chlorite with some secondary pyrite , based on X-ray diffraction analyses of insoluble residues of the mud-size fractions (<4μm) of all basal muds (Fig.10).

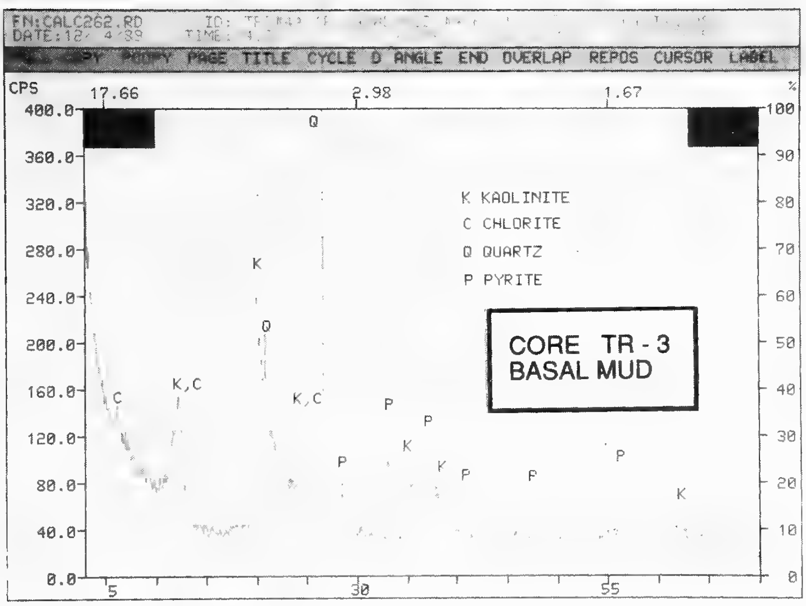

Figure 10. X-ray diffractogram of minerals in the non-carbonate fraction of the basal mud from vibracore TR 3.

Radiocarbon Dates

A total of twenty three mangrove peat samples were radiocarbon dated (Table 1). All of these dates have been plotted on the cross section (Fig.6), except for the two dates from TR 7, which is the one vibracore collected north of the transect line. As mentioned earlier, corrections were made for the thickness of peat sections that were compacted during vibracoring. In plotting the depth locations of dated peat samples, however, no corrections were made for natural compaction of the peat, which is difficult to quantify (A. C. Neumann, personal communication, 1995). Samples near the base and from near the top of peat sections would probably show little effect of natural compaction, but the few midsection samples could have been plotted at depths below those at which the peat was formed.

The oldest dates were from the west coast of the island (TR 1 - 6920±80) and from the area of slumping (TR 5 - 6920±100). Accumulation rates were highly variable, ranging from a maximum of 4.3 m/1000 yrs to a minimum of 0.4 m/1000 yrs. The accumulation rates for the top sections of two cores in areas of present-day mangrove growth were both representative of the minimum rates for mangrove peat accumulation in the Tobacco Range system (0.5 m/1000 yrs for TR 1 and 0.5 m/1000 yrs for J).

DISCUSSION

History of growth of Tobacco Range

If we accept the general trend for the late Holocene rise in sea level shown in Figure 11, we can see that mangrove communities were thriving in deeper lagoonal areas (Halley et al., 1977) before the Pleistocene relief below Carrie Bow Cay was flooded about 8000 years ago. In areas such as Tobacco Range, where the Pleistocene limestone surface is less than 10 m below present sea level, these mangrove communities, with accumulation rates of up to 4 m/1000 yrs (Table 1), were capable of keeping pace with the rising seas, eventually forming the present-day mangrove islands in this general area of the Belize Barrier Reef. In contrast, the areas south of our study site, where the Pleistocene limestone is considerably deeper, 15 m at Boo Bee Patch Reef (Halley et al., 1977) and 20 m at Channel Cay (Westphall, 1986), the accumulation of peat could not keep pace with the late Holocene rising seas and coral communities became established on areas of high Pleistocene limestone relief. In the Channel Cay area, mangrove communities have become established on some of the coral buildups, which now have a thin mangrove peat capping.

The peat accumulation rates at Tobacco Range have been highly variable, but the values of up to 4 m/1000 yrs are comparable to those accumulation rates commonly associated with active coral-reef growth. This is in marked contrast to Purdy's (1974) findings where he noted differential sedimentation rates between coral accumulations (average of 2.7 m /1000 yrs) as compared to the mean value of 0.2 m /1000 yrs for lagoonal peat deposits, with a maximum value of only 0.3 m/1000 yrs.

The overall late Holocene history of this area is one of a flooding of the continental shelf about 9000 yrs ago, initially through passes in the outer Pleistocene ridge system that provided the foundation for the present-day barrier reef. With the flooding of the inner lagoonal areas, mangrove communities began to flourish. Some of these communities in

Table 1
Radiocarbon Dates and Accumulation Rates for Mangrove Peat Samples from Tobacco Range, Belize

Core or Probe Hole	Depth(m) of Recovery Below Mean SL	C-14 Laboratory Number	C-14 Age Years BP ±SD	Accumulation Rate m/1000y
TR 1				0.5*
	0.97m	Beta - 22916	2090 ±70	
				4.0
	3.30m	Beta - 22917	2670 ±90	
				1.1
	7.91m	Beta - 22918	6920 ±80	
TR 2	1.16m	Beta - 22919	1710 ±60	
				1.0
	3.01m	Beta - 22920	3550 ±90	
				0.4
	3.84m	Beta - 22921	5450 ±75	
				4.1
	8.34m	Beta - 22922	6550 ±95	
TR 3	0.62m	Beta - 22923	2380 ±90	
				1.2
	3.51m	Beta - 22924	4790 ±80	
				1.9
	5.82m	Beta - 22925	6040 ±100	
TR 4	6.33m	Beta - 22926	5510 ±110	
				0.8
	6.75m	Beta - 22927	6010 ±80	
				2.8
	7.53m	Beta - 22928	6290 ±90	
TR 5	4.81m	Beta - 22929	5470 ±100	
				3.0
	7.34m	Beta - 22930	6310 ±90	
				4.3
	9.93m	Beta - 22931	6920 ±100	
TR 6	6.97m	Beta - 22932	5790 ±110	
				1.7
	8.25m	Beta - 22933	6570 ±90	
				4.0
	9.38m	Beta - 22934	6850 ±90	
TR 7	2.42m	Beta - 22936	3050 ±80	
				1.6
	8.04m	Beta - 22937	6570 ±80	
J				0.5*
	1.50m	Beta - 31605	3550 ±80	
				2.6
	7.19m	Beta - 31606	5770 ±110	

* Accumulation rate for top section of actively growing mangrove island--taking into account 2 cm (TR 1) and 10 cm (J) relief above mean sea level.

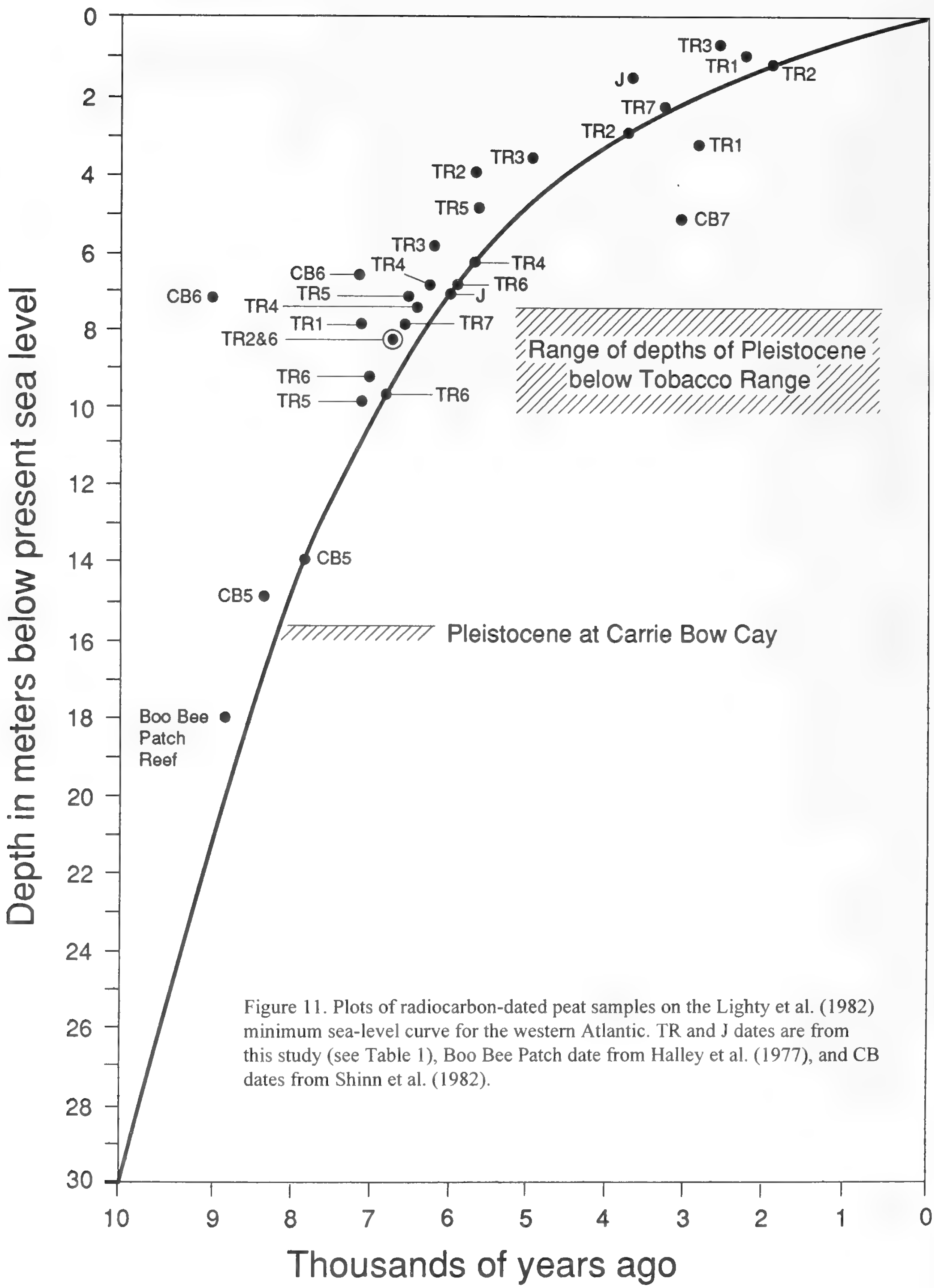

Figure 11. Plots of radiocarbon-dated peat samples on the Lighty et al. (1982) minimum sea-level curve for the western Atlantic. TR and J dates are from this study (see Table 1), Boo Bee Patch date from Halley et al. (1977), and CB dates from Shinn et al. (1982).

deeper areas of the lagoon became submerged by the rising seas, but others survived to flourish along the mainland coast and others on areas of high Pleistocene relief.

In the Tobacco Range area, with the decrease in the rate of sea-level rise about 3000 yrs B.P. to less than 1 m/1000 yrs (Fig.11), the peat accumulations became more stabilized resulting in the subsidence of mature deposits (Cameron and Palmer, this volume) and erosion of island shores with a reduction in the size of living mangrove cover. Consequently, relict peat was left stranded on the sea floor off most of the largest (northeastern) island of Tobacco Range. At present, the east coast is slowly accreting windward with the vegetation (mostly the red mangrove *Rhizophora mangle*) growing over debris and mud that is collecting along this coastline (Fig.12). In contrast, the leeward west coast is being actively eroded (Woodroffe, 1995, this volume), primarily during winter storms from the northwest, with the result that there is very little sediment overlying the submerged peat surface along this coast and the roots of mangroves and coconut palms (*Cocos nucifera*) are being actively undercut (Fig.13).

Basal Muds

The basal muds found in each vibracore and in sediment-probe samples commonly contain rock fragments of the Pleistocene limestone that lies directly below these muds (Fig.6). Similar basal mud deposits have been reported from below peat from northern Belize--" basal clay unit" (High, 1975, p.84) and "basal clay" (Ebanks, 1975, p.270). Similar basal muds were also recovered in four sediment cores collected around a small patch reef near Wee Wee Cay--"terrigenous clay" (Halley et al., 1977, p.32).

The Tobacco Range basal muds, which contained a complex mixture of calcareous mud, non-carbonate clays, quartz, peat, fragments of limestone, and Holocene carbonate skeletal debris, appear to be a reworked residual soil that formed on the subaerially exposed and weathered Pleistocene limestone surface. High (1975) considered the basal clay in northern Belize to be a coastal marsh deposit associated with a residual soil. His deposits, however, showed a "lack of shell material" (High, 1975, p.85) and an "abundance of montmorillonite". Montmorillonite settles rapidly from the water column in comparison to other clay minerals (Pierce and Siegel, 1979) and is commonly a dominant constituent of nearshore clay assemblages.This abundance of montmorillonite and absence of carbonate skeletal debris contrasts with Tobacco Range muds that contained skeletal fragments, notably marine molluscs and echinoids, and are dominated by kaolinite/chlorite clay minerals (Fig.10). Both of these characteristics suggest a more open-water influence on the development and reworking of residual soil at Tobacco Range in comparison to the inshore coastal deposits reported by High (1975) and Ebanks (1975) in northern Belize.

Slumping

The two vibracores (TR1 and TR2), on the west coast and adjacent to the fracturing and slumping, contained very long basal intervals of over 5 m of fine-fibered peat (Fig.6), which appears to outcrop in the fractured wall exposures. It is this easily erodible fine-fibered peat, exposed to oxidation, gravity flow and bottom-currents (Littler et al., 1995, this volume) that results in an undercutting of the more coherent upper sections of broad-fibered peat. These processes of undermining the overlying peat deposits could have been initiated and subsequently enhanced by forces associated with severe storms and earthquakes (Littler

Figure 12. A thick growth of mostly red mangove(*Rhizophora mangle*) overgrowing sediments accumulating along the muddy windward east coast of the northeast island of Tobacco Range.

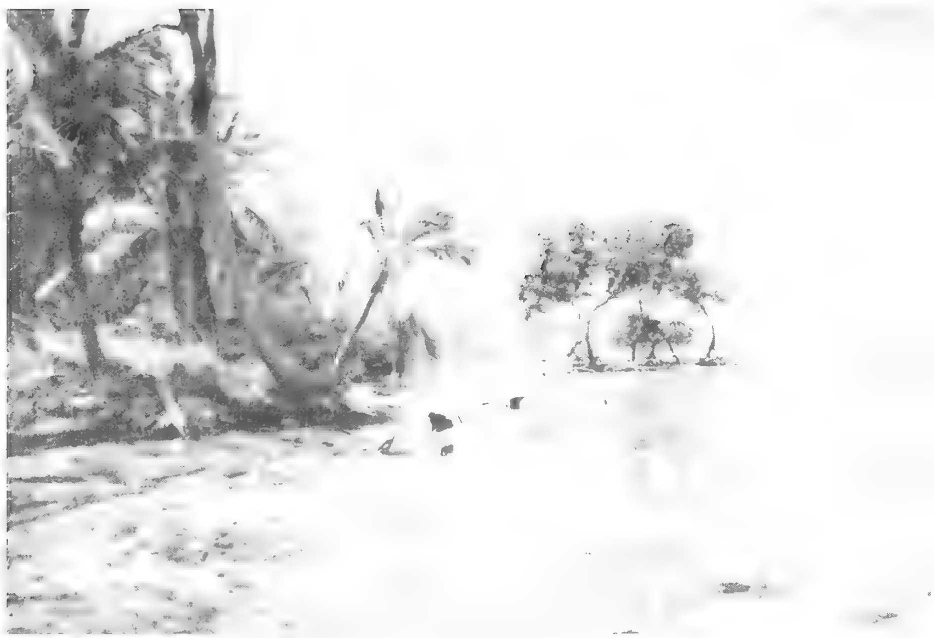

Figure 13. Active erosion along the west coast of the northeast island of Tobacco Range is indicated by the thin sediment cover on stranded peat (in foreground) and exposed roots of coconut palms (*Cocos nucifera*).

et al., this volume). This undermining has resulted in a fracturing of the submerged peat and slumping off of large blocks of peat into a watery muddy matrix of the fine-fibered peat (Fig.14).

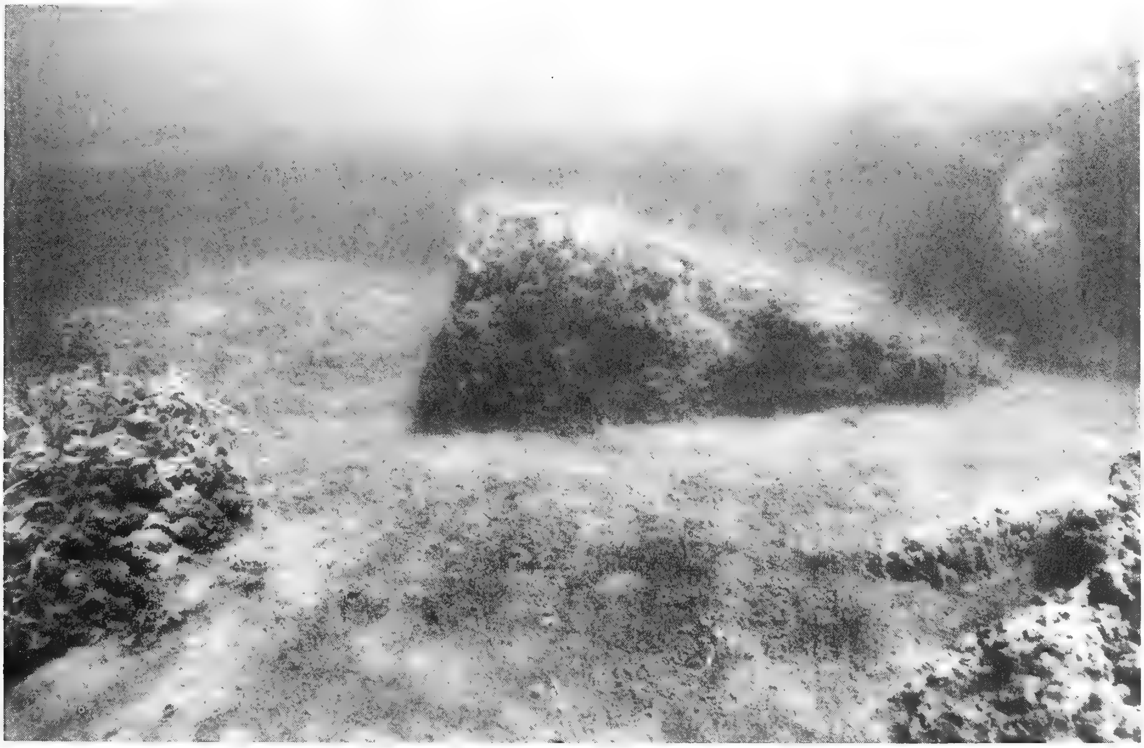

Figure 14. Slump blocks of broad-fibered peat(with *Thalassia* still growing on their upper surfaces) partially buried in a slurry of fine-fibered peat and scattered carbonate sediments.

A Belize Sea–Level Curve

A plot of the radiocarbon dates of peat from this study along with peat dates from other lagoon cores in this area of Belize (Halley et al., 1977; Shinn et al., 1982) confirmed that the *Acropora palmata* minimum sea-level curve for the western Atlantic (Lighty et al., 1982) is valid for the general region of Belize (Fig.11). Almost all of the peat dates plotted on this sea-level curve or within a 3 m envelope above it -- including the dates from the area of recent slumping. Indeed mangrove dates should plot above a sea-level curve that is based on shallow-water coral radiocarbon dates and the peat dates of this study provide an upper mangrove limit for this minimum sea-level curve.

There are, however, three notable examples where the peat dates did not plot close to this sea-level curve (Fig.11). One date of 8808±600 yrs B.P. for CB6 at 7.32 m (Shinn et al., 1982) was much older than expected. This peat was associated with terrigenous sediments and could have been contaminated with older debris. On the other hand, the two samples that plot below the curve, CB7 with a date of 2861±190 yrs B.P. at a depth of 5.22 m (Shinn et al., 1982) and the TR1 date of 2670±90 yrs B.P. at a depth of 3.30 m could both

have been contaminated by younger root penetrations.

These findings contrast sharply with the Belize sea-level curve proposed by Westphall (1986), which was based on published peat dates (Purdy, 1974; Halley et al., 1977; and Shinn et al., 1982) and indicates an abrupt decrease in the rate of sea-level rise about 5500 years ago at a depth of 1 m. The data that supports the shallow-water depths, however, are highly questionable and are not all derived from Purdy (1974) as indicated by Westphall. Indeed it appears that most of these dates came from Ebanks (1967) and were probably obtained from reworked or freshwater peats on the Shallow Pleistocene shelf in nothern Belize. The dates in Figure 8 follow the trend of the western Atlantic minimum sea-level curve and show no evidence for water depths as shallow as 1m about 5000 years ago. It is highly unfortunate that the Westphall sea-level curve has been introduced into the literature as evidence that sea-level curves of some Atlantic sites are comparable to those of Australia and the central Pacific (Davies and Montaggioni, 1985; Woodroffe, 1988).

CONCLUSIONS

1. The mangrove island complex of Tobacco Range was initiated as a mangrove community on a weathered Pleistocene limestone surface about 7000 years ago. The initial accumulation of mangrove peat has kept pace with the rising sea levels of the Holocene transgression to form the present-day island systems with peat sections of up to10 m thick. With the marked decrease in the rate of sea-level rise over the last 3000 years, there has been a stabilization in the growth of these mangrove islands, which has resulted in considerable erosion and reduction in size of the living mangrove cover.

2. The thin basal mud sections below the peat at Tobacco Range represent an open-water reworked residual soil that covers the eroded Pleistocene limestone.

3. Slumping off the west coast of Tobacco Range appears to be related to the removal of readibly erodable fine-fibered peat that is exposed below the upper sections of more resistant broad-fibered peat.

4. Radiocarbon dates of mangrove peat from Tobacco Range and surrounding areas confirm that the minimum sea-level curve for the western Atlantic (Lighty et al., 1982) is applicable to the Belize region.

ACKNOWLEDGEMENTS

Special thanks for field assistance in 1987 from Barrett L. Brooks and Anthony G. Macintyre and in 1989 from Cornelia C. Cameron, Allan G. Macintyre, and Anthony G. Macintyre. We also wish to thank William T. Boykins for laboratory assistance and Mary E. Parrish for assistance with graphics. We gratefully acknowledge David R. Stoddart and Robert N. Ginsburg for critically reviewing the manuscript and offering suggestions for its improvement. Fieldwork for this research was supported by the National Museum of Natural History's Caribbean Coral Reef Ecosystem Program (CCRE Contribution Number 456).

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NO. 431

THE MANGROVE PEAT OF THE TOBACCO RANGE ISLANDS, BELIZE BARRIER REEF, CENTRAL AMERICA

BY

C.C. CAMERON AND C.A. PALMER

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WASHINGTON, D.C., U.S.A.
AUGUST 1995

Cornelia C. Cameron, Tobacco Range
March 24, 1989

CORNELIA CLERMONT CAMERON (1911-1994)

Cornelia Cameron, an internationally recognized peat geologist, died of cancer at age 83 on August 5, 1994, at her home in Winchester Virginia. Her work helped elevate the study of peat and its resource potential to a respected scientific discipline. Cornelia received her B.A. and M.S. degrees in botany and a Ph.D. in geology (with emphasis in geomorphology) from the University of Iowa. She worked in the earth sciences sections in museums in New York and Missouri from 1940 to 1942, and then taught geology at Stephens College in Columbia, Missouri, for 9 years.

From 1951 until her death in 1994, she worked for the U.S. Geological Survey. Her early U.S. Geological Survey work was in the Military Geology Branch, where she did terrain analysis based on literature, photo interpretation and field studies; she was senior author of a 262-page Army Field Manual on terrain intelligence. From 1953 to 1964, she did field work in Japan, Korea, Taiwan, Nigeria and the Caribbean Islands, turning out 50 reports on water resources and engineering construction and foundations. In Korea she served as an engineering geology consultant to the United Nations forces.

Her interest in peat started after the Atlantic coastal storm of March, 1962, which greatly accelerated normal beach erosion. The surfline at Dewey Beach, Delaware, exposed extensive peat formations and tree stumps. The geologic study and carbon- 14 dating of the peat collected by Cornelia indicated that it had been part of the landward side of the lagoon between the barrier island and the mainland forest only 200 years earlier. Cornelia showed by this study that relative sea level rise had a faster rate than before realized. She then considered other facts to be gained from the study of peat, including correlation of vegetation with satellite images, analysis of clues to surrounding mineral deposits, and the resource potential of growing vs. static peat areas. She persuaded the U.S. Geological Survey to recognize the need for research on peat and began with the peat resources of Appalachia in 1965. In time she became known worldwide as a leading authority on peat resources and their quality. Her improvements in the McCaully sampler for measuring the stratigraphy of peat deposits changed the technology of peat studies. She was influential in shifting the peat industry from its emphasis on fuel use to agricultural purposes as well. From an initial focus on sphagnum peat, she proceeded to study all types of peat worldwide. In recent years, she carried out studies at the request of the government of Indonesia in Sumatra and Kalimantan (Borneo).

Of the more than 110 publications in her bibliography, Dr. Cameron's most notable include one of the first geology textbooks in this country that relates geology to society, Earth, Sky and Human Affairs, 1946, published by Stephens College. More recently, her 1983 paper on variations in mineral content of peat, a 1984 paper on the relationship between geology of peat deposits and their exploration and economic consideration, and a 5-volume set on the peat resources of Maine have assured Dr. Cameron's position as the world's foremost expert on peat deposits.

Cornelia's work received much recognition. She was a member of Sigma Xi. In 1969 she became the peat commodity geologist for the U.S. Geological Survey. In 1984, the legislature of the State of Maine voted a commendation in recognition of Cornelia's vital role in delineating peat as an important resource of that state. She also received letters of appreciation from the governor of Maine and its legislature for her outstanding work in

Maine, and from the Roosevelt-Campobello International Park Commission in Maine where she was called on to map the peatlands. In 1977, she received the Meritorious Service Award of the Department of Interior and, in 1986, she received the Distinguished Service Award of the U.S. Department of the Interior. In 1990, she received the Department of the Interior's Public Service Recognition Award as well as the Distinguished Alumni Achievement Award of the University of Iowa. She also served for 13 years as Vice Chairman of the International Peat Society.

Both of Cornelia's parents were botanists, with B.A. and M.A. degrees. While her mother completed work for a Ph.D., her father was a professor of natural sciences and agriculture in Missouri, and did much lecturing and photography in these fields, especially on the Chautauqua circuit. They returned to the University of Iowa, where both had studied, but her father died as a result of the influenza epidemic of 1918, when Comelia and her brother were small children. Her mother, who had taught in the Iowa City schools for several years, then supported the family by operating a farm they had purchased. When Cornelia went to work with the U.S. Geological Survey her mother lived with her. Her mother accompanied Cornelia on her field work until her mother was 103 years old. Her mother's botanical work was essential to coordinating the ground studies with satellite images.

Field geologists benefit from an awareness of the local people and sociology. Cornelia and her mother mastered this skill in many situations. In many areas around the world, people were leery of government representatives, and care was needed in approaching the local people. Cornelia's mother often maneuvered the first contacts, winning everyone with her gracious manner, and introducing Cornelia to the local people, which allowed Cornelia information she would never have been able to obtain in other ways. One day when Cornelia was in Cuba before the Bay of Pigs invasion, she was working in the field when her mother, who had stayed behind in the car, was approached by a truck full of guerrillas. Her mother simply charmed the guerrillas by telling them that she was a Canadian tourist, and they drove off.

Cornelia was full of surprises. She always wore khakis in the field and was working in Japan when a general gave a formal dinner. To everyone's astonishment, Cornelia appeared in a satin gown with matching elbow-length gloves. When asked about it later, she replied that one had to be prepared for proper occasions.

Cornelia was actively working until just before her death. She completed a full season of field work in Oregon and Wisconsin in 1993 and was involved in the geochemistry of peat deposits in the Midwest as part of a project on herbicides in soil and groundwater. She was also active in a coring study as part of the Great Lakes Wetlands program. Her final manuscript follows in this volume. In the end, she was concerned about all the things she had yet to do, but we who were touched by her life will always appreciate all the wonderful things she accomplished.

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THE MANGROVE PEAT OF THE TOBACCO RANGE ISLANDS, BELIZE BARRIER REEF, CENTRAL AMERICA

BY

Cornelia C. Cameron[1] and Curtis A. Palmer[2]

ABSTRACT

Core samples of Holocene mangrove peat were collected onshore and offshore of the north island of Tobacco Range to analyze the peat texture and composition. These characteristics of the peat were then related to the geological history of this island and to the flora that formed it. Chemical data determined by instrumental neutron activation analysis as well as ultimate and proximate analysis suggest that these elements have a mainland origin from volcanic ash or possibly other sources. The heterogeneity of the ash and trace element content in the peats may be accounted for by sea level changes, rate of plant growth and decay, and types of vegetation.

INTRODUCTION

Tobacco Range is a circular group of mangrove islands surrounding a central lagoon on the outer platform of the Belize Barrier Reef about 2 km west of Tobacco Cay in the Caribbean Sea (Fig. 1). The mangrove islands in this area are underlain by mangrove peat, which rests on limestone bedrock of Pleistocene age (Macintyre et al.,1995, this volume).

Tobacco Range is about 5 km long and 2 km wide. The largest island, at the north, which contains small shallow lagoons and tidal waterways, is the subject of this study (Fig. 2). Two long narrow islands to the south and a series of smaller islands complete the lagoonal fringe. Cores taken at the north island show a maximum thickness of 10 m of peat developed chiefly from plants of red and black mangrove communities. Peat also extends below the ocean surface on either side of Tobacco Range The maximum elevation of the peat surface on the north island is only 20 cm above mean sea level (MSL). The purpose of this study was to examine and characterize the subsurface peat strata from a transect series of cores used for radiocarbon dating of the Holocene history of the Tobacco Range (Macintyre et al., 1995, this volume).

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METHODS

Cores were taken along a northwest-southeast transect (Figs. 2 and 3) of the north island to define the characteristics of the subsurface. A vibracore was used to obtain core TR1 onshore and all cores offshore including core TR3 off the east coast. All cores were described and sampled in the laboratory after transport in boxes. Some moisture was lost in the process. Later, hand-operated Macaulay and Davis peat samplers were used on land and off the east coast to collect the remainder of the cores. These cores were described and sampled in the field, and transported to the laboratory in moisture-proof containers.

The pH of all samples was measured in the laboratory and ash content was recorded as percent dry weight. The dry weight was obtained by heating the sample to 110° C after air drying for several weeks. The ash content represents inorganic material remaining after ignition at 550°C for 24 h. Element content was obtained by instrumental neutron activation analysis at the U.S. Geological Survey from representative splits of each sample. In addition, a few samples were analyzed by Dickinson Laboratories, Inc.[1] for proximate and ultimate analyses, BTU, and forms of sulfur.

RESULTS

The Geological Setting of the Peat

The Yucatan Block consists of an almost continuous sequence of Cretaceous to Pliocene shallow water limestone deposits. During the Pliocene the entire Yucatan block, upon which Belize lies, was tilted northward to form the present Campeche Bank. A set of north-northwest-trending normal faults formed submarine escarpments on the east. These faults influence the shape and bathymetry of the Belize shelf. An echelon parallelism in many of the linear segments of the coastline, the shelf-edge, and the offshore atolls, suggests fault control by known inland surface-expressed faults (Miller and Macintyre, 1977).

The Belize Barrier Reef is also roughly parallel to the strike of the normal faults. The upthrown blocks apparently provided a shallow water foundation for initial coral development during the Pleistocene. Reefs appear to have formed in areas of slow but continual subsidence, a periodic condition typical of Pleistocene time and continuing into the Holocene (Adey, et al., 1977). Meanwhile, mangrove peat was also accumulating in an ever thickening layer.

The peat collected in cores along the study transect (Fig. 3) rests on or is close to the bedrock. Because mangroves can only initiate growth in sheltered places, the initial mangrove seedlings took root in the low-energy environment behind the active coral reef where they were protected from the full force of ocean waves (Chapman, 1976; Woodroffe, 1983). During this time of initial settlement, the sea floor was covered with a residual soil and carbonate sand from leached limestone that was subaerially exposed during the

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[1]Any use of trade , product, or firm names is for descriptive purposes only and does not constitute endorsement by the U. S. Government..

Pleistocene. Except for a thin, exposed pavement directly shoreward of the reef crest, all reef flat and lagoonal shallow sediments, over a distance of at least 24 km, were uncemented, which permitted the rooting of mangroves.

Radiocarbon peat dates from these cores indicate that the Tobacco Range mangroves were established on or near the Pleistocene limestone surface at least 7,000 years ago (Macintyre et al., 1995, this volume). At this time, the shorelines of land areas were far westward beyond the present shorelines of Tobacco Range. The dates shown on the cores along the northwest-southeast traverse (Fig. 3) plot on or within 3 m above the minimum sea-level curve for the Caribbean and tropical western Atlantic Ocean based on growth of a shallow-water coral Acropora palmata reef framework (Macintyre et al., 1995, this volume)

Mangrove communities have traced the rising sea levels for the past 9,000 years and today are surviving on the high Pleistocene relief of the Tobacco Range. The rising sea level during the Holocene transgression flooded many mangrove communities and covered the forest floor west of Tobacco Range to depths of 6 m. The mangroves to the east, however, were established on a shallower Pleistocene surface and continued to grow while sea level was rising more slowly. Thus, peat accumulation could keep pace with rising sea level, although not at a regular rate in every locality (see Macintyre et al., 1995, this volume). During the past 7,000 years, peat accumulated to a maximum thickness of 10 m in the interior of the north island as measured at core site F.

Peat

The total land surface covered by peat to a depth of more than 30 cm is estimated by Kivinen and Pakarinen (1980) to be approximately 500 million hectares. Geologically, peat is very young and belongs almost entirely to the Quaternary. The unburied deposits are mostly of Holocene age. Although peat deposits of varying thickness and extent are common and widespread in many types of geologic settings throughout the world, mangrove peat is restricted to mangrove swamps in salt and brackish water along tropical and subtropical coastlines and islands. Mangrove swamps are located mostly between latitudes 25°N and 25°S, below the limits of freezing weather (Mitsch and Gosselink, 1986). Mangrove communities can develop only where there is adequate protection from wave action (Chapman, 1976). Their growth is restricted to the intertidal zones which are narrow at Tobacco Range. At Carrie Bow Cay, about 10 km away, the mean tidal range is only 15 cm. Tides are of the mixed semidiurnal type (Kjerfve et al., 1982). This restricted tidal range makes the mangrove peat highly useful for dating relative sea-level rise.

Peat consists of partly decayed plant matter, inorganic minerals, and water in varying proportions. The American Society for Testing and Materials (ASTM, 1969) defines quality standards for commercial peat that generally apply to that of fresh water origin. Accordingly, a "peat" must contain less than 25 percent dry weight inorganic material or ash to be used for agricultural or horticultural purposes. Peat formed in brackish or salt water contains soluble salts that increase ash content. In this paper, peat containing less than 31 or 32 percent ash content is considered "peat." "Muddy peat" contains roughly 32 to 75 percent ash content, and "peaty mud" greater than 75 percent.

Major differences in peat accumulation result from the variety of plants from which peat is formed, the relationship of the deposits to the water table regime, and the degree to which part of the peat has decayed or been removed by fire or storms (Cameron 1988). These factors are affected by climate, ground water level, and surface topography of the wetland. The inorganic components of peat include both minerals from the substrate and elements absorbed by roots from ground water or surface water. Also, minerals are introduced to the peat-forming environment as suspended detritus, volcanic ash, or are precipitated from solution. The peat of Tobacco Range derived its inorganic components mostly from sea water, and from the limestone bedrock and residual soil in basal sections. Both the organic and inorganic components of peat are affected by the chemistry and microbial activity of the depositional systems.

Several factors are known to govern peat quality irrespective of inorganic components. Fluctuating water tables within the deposit can permit oxygenation of the organic material, thereby allowing aerobic microbes to decompose plant fibers. Where water tables remain high, peat accumulates faster than it decays and builds up the deposit. Low ash peat accumulation can continue until the water table declines during dry weather or through drainage changes cause decay which raises the ash content and destroys fibers. The surface of the peat is thereby lowered.

If the rate of mangrove peat accumulation is faster than the rate of sea level rise, the peat may reach an elevation at the highest level of the tidal range. Nutrients to the roots are cut off at this boundary and decay sets in, and the peat surface is subsequently lowered by erosion to form a depression. In the depression, a pool may form that may become part of a tidal waterway in which new young trees take root and thrive. As sea level transgression continues, the cycle begins anew with young thriving mangroves and relatively rapid low ash peat accumulation in former depressions.

Physiography Along the Cored Traverse

Interpretation of the environmental history recorded by the peat stratigraphy of Tobacco Range requires knowledge of the physiography of the modern peat surface. The surface of the north island is marked by flats, low rises, ponds, and tidal waterways. Mangroves nourished by tidal water flourish and produce a biomass that is the source of peat and builds the peat surface at a rate faster than sea level rise. As noted earlier, uninterrupted peat may reach a height above the range of tidal nourishment where decomposition occurs; decomposition then exceeds accumulation, and the peat surface may subside to hold a pond within the tidal range. A new cycle may begin again. Hurricanes also cause interruptions in peat accumulation by removing vegetation and fostering decomposition of the peat surface. As the sea transgresses and the surface of the island of peat rises, layers having lower ash content represent relatively rapid mangrove growth. These alternate with layers of greater ash content that represent the materials of ponds and waterway bottoms and flat surfaces denuded by hurricanes. Alternation of layers of lower and greater ash content is shown by patterns in the cores (see Figs. 4, 5, 6, and 7).

Submerged slump blocks of peat occur in the cores collected from unstable mangrove environments. Fracture patterns occur where relatively fresh peat rests on partly decomposed peat muds. Littler et al., (1995, this volume) suggest that slumping occurred

as a result of aerobic decomposition and bottom current erosion. During, periods of severe wave activity, blocks of submerged peat along the edge of the island slump down slope to become submerged in old fine fibered peat. The offshore cores, TR4 and TR6 (Fig. 3), are believed to contain anomalous peat talus broken from the sides of the island during severe wave action.

Vegetation Reflects the Modern Physiography

The vegetation types vary along the island transect (Figs. 2 and 8, Woodroffe, 1995, this volume). The types are distinct and can be recognized in cores because they represent environments that are repeated at least in part throughout the development of Tobacco Range. These vegetation types are distributed from core B on the east coast or windward side of the island across the length of the traverse to the western or leeward side at core TR1.

***Avicennia* Open Woodland and *Rhizophora* Woodland**

In the traverse that begins on the windward (eastern) side, a vegetation type classified as *Avicennia* open woodland with *Rhizophora* (Woodroffe, 1983) grows on a gentle rise above sea level. Red mangrove (*Rhizophora*) dominates this area. Scattered black mangrove *Avicennia* also grows but is shorter and less robust than in more protected inland areas. Marsh grass and sprawling woody vines are common at the core B location, where little if any peat is accumulating. In addition to decomposition, fine-grained sediment washed over the area contributed to the high ash content in the upper part of core B (Fig. 3).

Unvegetated Flats

The adjacent "unvegetated flats" sampled in cores D and E are topographically lower in height than the site at core B (Fig. 8). Vegetation apparently had been killed by flooding, possibly during a hurricane. The flats are now covered by a regrowth of red mangrove and Batis, a low shrub having fleshy leaves. Pools of stagnant water are juxtaposed with bare areas of fine and largely algal-derived surface sediments. Firm mangrove peat that lies below all of these flats suggests that the community is growing on a storm-eroded peat surface that undoubtedly is undergoing decomposition.

***Rhizophora* Woodland**

The unvegetated flats give way landward to *Rhizophora* woodland (Fig. 8). This woodland is well watered and is composed of dense red mangrove at least 4 m high. It apparently escaped the hurricane damage that appears to have destroyed the vegetation on the east edge of the island. Rapid accumulation of low ash peat is characteristic of this environment.

***Rhizophora* Scrub**

There is a slight increase in topographic relief in the central part of the island west of the *Rhizophora* woodland. In this area, classified as *Rhizophora* scrub, red mangrove about 2 m in height is dominant. The trees are twisted and probably old. The lower limbs

are covered with yellow lichens and a thick litter of leaves lies on the ground. These trees appear to be suffering from nutrient deficiency, a typical phenomenon of both temperate and tropical wetlands having raised surfaces (Cameron et al., 1989). At this location on Tobacco Range, trees are almost beyond the reach of tidal nutrients. The peat that has accumulated under this *Rhizophora* scrub community is undergoing decomposition faster than it is accumulating. If a depression forms from continuing decomposition, another pond may occupy the area, or perhaps the neighboring waterway will shift to this location and begin a new cycle of accumulation.

The flourishing young red mangroves in shallow waters or rooted in the mud in nearby open water ponds and lagoons contrast sharply with the older mangroves. At the present time, these are shrubs that represent the beginning of another mangrove growth cycle. The mud that these young trees are rooted in rests on peat having lower ash content. The stems and leaves of these young mangroves fall on the saturated substrate and rapidly accumulate to form a low ash peat.

Rhizophora Thicket

The *Rhizophora* thicket lies at a slightly lower elevation than *Rhizophora* scrub. The red mangroves of this community are taller, about 2 to 4 m in height. Peat having an ash content more than 31 percent could be expected if the prop roots continue to maintain their position above the optimum tidal nutrient supply.

Western Part of the Island

Continuing westward along the traverse is another area of *Rhizophora* scrub with old trees on high peat surfaces and young trees in and around the margin of ponds forming thickets. The *Rhizophora* scrub then grades into an *Avicennia* woodland dominated by black mangrove. Stands of black mangrove dominate this leeward side of the island and the tip of the windward northeast coast (Woodroffe, 1995, this volume). *Avicennia* open woodland fosters relatively rapid production of low ash peat.

Physical Description of the Peat of Tobacco Range

Cores taken through these different environments all consist of peat having visible amounts of ash that generally overlies peaty mud and mud. Red and black mangroves, the dominant trees of the north island, are the source of most of the peat which is composed of partly decayed plant structures that are unique to mangrove. In order to survive in an environment of high salinity, storms of hurricane proportion, and anoxic soil chemistry, mangroves have developed structures to control concentration of salts in the tissues: prop roots, pneumatophores, and viviparous seedlings.

Distinguishing features of mangroves include prop roots of red mangroves (*Rhizophora)*, and pneumatophores in black mangrove (*Avicennia*). Pneumatophores stand like pencils, 20 to 30 cm above the ground. Both prop roots and pneumatophores have small pores through which oxygen enters the plant when exposed to the air at low tide. If the tidal range stabilizes above the prop roots and pneumatophores, the mangroves die from lack of oxygen (Macnae, 1963; Day, 1981).

Red mangroves have seeds that germinate while they are still on the parent tree.

These long cigar-shaped viviparous seedlings are an adaptation for seedling success in shallow anaerobic waters and sediments that, otherwise, would prevent seeds from sprouting. The seedlings fall from the branches and root if they fall on sediment or float and drift in ocean currents and tides. The seedlings assume vertical positions and the matrix of interwoven roots that characterize red mangrove peat is initiated.

The peaty muds and muddy peats that rest on a thin layer of gray clay or "basal muds" (Macintyre et al., 1995, this volume) beneath the root matrix often contain *Thalassia* (sea grass) that also forms part of the substrate over limestone. Various amounts of unconsolidated rock fragments and other inorganic sediment may also be included. The overlying peat is largely compact, inelastic, and has structured fine fibers representing the narrow interwoven root fibers derived from *Rhizophora*. Broad, thick fibers tend to be derived from stem, prop roots, and pneumatophores of *Avicennia*, and of course the red mangrove, because the two types occur together. Various amounts of unconsolidated inorganic sediment may be mixed with the root and stem fibers of the peat along with more or less decayed leaves, twigs, and other plants living in the mangrove habitat.

A striking characteristic of the entire deposit above the base is its alternating zones of higher and lower ash content. These higher ash zones are peaty mud and muddy peat, containing remains of microscopic aquatic plants that were alive on the floors of ponds and lagoons and include the remains of molluscs and other aquatic invertebrates.

The mud and peaty muds that occur above the bases of the cores appear similar to the mud flats and shallow water bodies on the island crossed by the core traverse (Fig. 2). They may represent ancient mud flats and pond bottoms similar to those at the surface today. This high ash material is much less permeable than the overlying fibrous peat. The decreased permeability of this underlying dense material produces a slippery contact. It is possible that under the stress of severe storms, the slippery contact encourages breaks. However the patterns of fractures at right angles to the shoreline and the oozing of dark humic waters at depth (see Littler et al., 1995, this volume) indicate that subsurface hydostatic flows may be leading to the decomposition and subsequent collapse of the fine fibered peat.

The peat formed from red mangrove tends to have a reddish color derived from the pink hue of the root cortex; peat from other sources appears grayer or browner. Highly decomposed peat appears fine grained and very dark in color.

Table 1 shows data for moisture, ash, percent volatile matter, percent fixed carbon, BTU, and percent sulfur determined by proximate analysis of two samples collected from cores on land (TR1 and F) and one core from below sea level (TR5), corresponding data for major elements, ash, and moisture determined by ultimate analyses, and corresponding data on forms of sulfur. All have similar ash contents (Table 1) and BTU values are not strikingly different, but the sample from the interior of the island appears to have a higher sulfur content than those from the margin and offshore. Decay of vegetation in a pond probably is the explanation for the higher sulfur values. Average acidity for the cores is mostly between pH 4.9 and 6.7, which is typical of a reef environment.

Ash Content of the Peat

Peat samples taken from the cores were analyzed for their organic and inorganic

contents (Tables 2 and 3). The data are arranged in order of the cores along the northwest-northeast traverse (Fig. 3) beginning with Vibracore TR5 at the northeast end. A relationship that appears among texture, permeability, and ash content is that a decrease in ash content together with increased porosity results in greater permeability.

Ranges in ash content in the cores of Tobacco Range are shown in Figures 4, 5, 6, and 7. Nondecomposed fibers were examined. Fiber shapes and sizes were largely related to the type of source vegetation in the mangrove communities. Fine fibers are largely associated with root networks of young red mangroves and all partly decomposed older peats; coarse fibers are associated with prop roots of red and black mangrove as well as the leaves and stems of the associated herbaceous plants. Oxidation results in dark-colored, weathered-looking friable fibers and reduces the thinner herbaceous material to a dense fine fibered mass. Decomposed material has higher ash content than the fresher material.

Ash content in these typical peat deposits is a complex issue. Ash consists of volcanic ash blown in from the mainland, sedimentary minerals from pond deposits, minerals precipitated from sea water, and minerals taken up by the plants. The average ash content of the peat in the interior sites of accumulation on the island is therefore higher than in cores at the edges of the island.

Vibracores TR2, TR1, and TR3 have average ash contents of 21.1, 26.6, and 18.5 percent in contrast to inland cores J, I, F, D, and B, that have average ash contents of mainly plant origin of 51.5, 30.0, 34.7, 31.3, and 36 percent, respectively. The increase of ash is attributed to the dominance of periods of slower growth and weathering at these sites. Offshore Vibracore TR5 has an ash content of 37.6%. This site is now more than 4 m below sea level (BSL), but prior to 5,000 yrs B.P. when peat accumulation occurred, the mangroves that deposited the peat may have not been at the edge of the shore. At the edge, they would have been easily reached by tidal currents enriched with nutrients.

Descriptions and details of individual cores

Vibracore TR5 (Fig. 4) is 5.8 m long taken at a depth of 4.2 m below MSL. Bedrock was not reached by the vibracore. The core represents the peat stratigraphy accumulated between about 7,000 and 5,000 yrs B.P., when the peat island was being built as the sea receded. Overlying the basal muddy peat is reddish-brown fine-fibered peat derived from young mangroves. This peat is overlain by one derived from a mature mangrove forest that provided a large wood and leaf matrix. The uppermost intervals sampled contain peat reworked by waves together with *Thalassia* fragments, sand pockets, and mollusc shells, all of which were a part of the sea floor.

Vibracore TR4 from 5.8 meters below MSL represents peat talus 2.8 m thick that slumped from land transgressed by the sea more than 5,500 yrs. BP. The upper part of the core is reworked broad-fibered peat and sand that later formed a bed for the growth of *Thalassia* below the sea surface.

Vibracore TR6, a 2.7 m long remnant between 5,700 and 7,000 yrs B.P. lies close to bedrock. It consists of sandy mud and muddy peat overlain by low ash, fine-fibered peat. Above this is decomposed fine-fibered peat that, in turn is overlain by a relatively fresh broad-fibered, low ash peat derived from both red and black mangrove. The uppermost sample is a dark brown and gray organic-rich watery mud.

Vibracore TR2 (Fig. 4), located just offshore 0.7 meters under the ocean surface, is 7.5 meters long and rests on limestone. The upper part of the core was reworked in the course of the sea's transgression and is sandy mud with sand pockets and sea shells. The upper middle tends to be broad-fibered peat whereas the bottom middle is more fine-fibered (Macintyre et al., 1995 this volume). The striking feature of this core is its predominance of fresh or lower ash permeable peat alternating with higher ash peat that indicate alternating periods of faster and slower growing red mangrove communities. The ash contents are between 10.7 and 28.8 percent except one sample (No. 25, Fig 4) in which it is as high as 31 percent.

Vibracore TR1 (Fig. 5) at the island's edge is also characterized by low ash peat. Like core TR2, it is favorably located for tidal nutrient supply to the mangroves and like TR2 the top of the core is dominated by broad-fibered peat whereas the bottom of the core consists mainly of fine-fibered peat (Macintyre et al., 1995 this volume). The ash content ranges between 15 and 30 percent through much of the core. Ash content is higher at the base, where the peat rests on clay over bedrock, but above the base ash content between 31 and 38 percent is reached at the top (samples No. 1 and No. 2), just above and below the 2-m depth mark (samples No. 7 and No. 8), at the 5-m depth (sample No. 13), and below the 6-m depth (sample No. 16). Thus, the alternation of fast- and slow-growing mangroves is sharply evident.

Probe holes A, K, and G were probed primarily to obtain depth to bedrock. These data are shown in Figure 3 and Tables 2 and 3. Probe hole J (Fig. 5) is located in the interior of the island where the mangroves receive nutrients from tidal waterways. Samples from probe hole J indicate that red mangroves were established on a totally exposed sea bottom about 5000 yrs BP in the organic material on the basal clay lying over Pleistocene limestone. They continued to thrive with a mixture of black mangrove while another meter of peat accumulated; the peat then weathered until the surface formed a depression holding a pond or tidal waterway, where the muddy peat (sample No. 47) accumulated (Fig. 5; Table 3). Young mangroves rooted and thrived, as interpreted from very fresh low ash peat (sample No. 46). During the past 3,500 years, the surface has been building until today it is high enough to be covered by low standing red mangroves.

Probe hole I (Fig. 6) almost 8 m deep, has a base of high ash peat interpreted as the deposit of red mangrove that took root on the sea bottom. Above this base peat was formed from the plants that grew as sea level rose, reaching a peak of rapid growth as indicated by a sample at a little over 6 m deep (sample No. 43) and then slowed indicated by samples in the next 2 meters, when black mangroves became more numerous. They were followed by a surface depression as recorded in a sample a little less than 3 meters in depth (sample No. 40), then peat in this core was formed from plants with an increased growth rate reaching a maximum rate at less than 2 meters in depth (sample No. 39). Finally, the rate of plant growth slackened until presently the still-living red mangroves are old and stunted. This surface will most likely subside as decomposition of the peat substrate overtakes accumulation.

Probe hole F (Fig. 6) extends from about 0.2 m ASL to bedrock at a depth of 10.19 below MSL and represents the thickest peat section sampled in this study. After red mangrove was established on the muddy sea floor over Pleistocene limestone, growth

remained remarkably uniform while 5 m of peat with an ash content of about 32 to 41 percent slowly accumulated in a swamp lying in the interior of the island. A pond then developed on the surface, which promoted more rapid growth of mangrove and accumulation of peat with lower ash content in water having much higher sulfur content (7.4 percent) than the muddy peat above or below where sulfur ranges between 3.8 and 4.3 percent. After the pond filled and the peat surface rose higher, mangrove growth slowed and the peat weathered somewhat until an elevation of 2.2 m (sample No. 29) was reached. Since then, mangroves have grown rapidly in and above a waterway with good tidal circulation until the surface today is almost out of reach of tidal influence, and the ash content is 26.3 percent.

Probe hole E is located on the unvegetated flats that were probably swept by a hurricane to expose the underlying substrate, which is a comparatively low ash red and black mangrove peat. The base of the core is similar to the other cores and is resting on Pleistocene limestone. Muddy peat and peat alternating through the core suggests rapid and slow mangrove growth corresponding to the rising and subsiding surfaces resulting from rapid and slow peat accumulation, which is caused by decomposition, or removal of vegetation by hurricanes, while sea level continued to rise.

Probe hole D (Fig. 7), also located on the unvegetated flats, has a history similar to Probe hole E. Red mangroves established themselves on the muddy sea floor of a limestone trough; peat accumulation was rapid at first (sample No.24) became slower until sea level rose over the site (sample No. 23), which led to rapid plant growth again (sample No. 22). The characteristics of the peat in the remaining 5.7 m of the 8.6-m core indicates growth was remarkably uniform, progressing at a moderately slow rate in a mixed red and black mangrove swamp until the hurricane swept the surface. Today the vegetation is once again becoming established.

In Probe hole D the core pH is above 6 at all levels and reaches 7.2 in the muddy peat (samples No.19, 20 and 21) that appear to be formed largely from a mixture of black and red mangrove prop roots together with the herbaceous vegetation, vines, and shrubs that are characteristic of the island interior. The greatest concentration of ash is in the muddy peat in the upper part of the deposit in cores 18 and 19, which have ash contents of 31.2 and 32.4 percent respectively. The low concentration of ash in the base of this core could be explained if ground waters moved down the limestone slope and dissolved the minerals in the ash and removed them from the system.

Probe hole B (Fig. 7), located on higher ground near the leeward shore in the *Avicennia* open woodland with *Rhizophora* vegetation type, extends from about 0.1 m above MSL to limestone in the bottom of the trough 9.53 m below MSL. The history recorded in the peat is typical of the development of the island's interior, namely an alternation of slightly faster and slightly slower rates of growth of an initial predominantly red mangrove forest followed by a mixed red and black mangrove forest and overlain by the deposits formed by washover of the shore by high seas.

Vibracore TR3 (Fig. 7) is located under shallow water at the edge of the island where tidal currents facilitated mangrove growth and accumulation of peat. Today the core is 0.2 m below MSL, and extends to a limestone ridge or platform about 6.5 m below MSL. The top of the core consists of a reworked peat surface that is the result of marine erosion.

It now lies under the sandy sea floor and *Thalassia* growth.

Probe hole C samples No.15, 16, and 17 are muddy peat having ash contents of 45.8, 49.8, and 35.4 percent respectively. The upper two samples, mixed with sand and shells, lie at a depth of 1.5 meters BSL. Like Probe hole D, this core is alkaline with a pH of 7.6 for the upper two samples and 7.7 for the lowest sample.

Trace Element Distribution

The trace element contents determined in the cores are highly differentiated and may help interpret differing concentration mechanisms. As shown by Figures 4, 5, 6, and 7, trace elements are distributed heterogeneously. Many elements vary by more than an order of magnitude within each core (see Table 3). There are also large variations in the average concentrations of most elements between cores.

The behavior of trace elements in the peat are greatly affected by their concentration in sea water. This is not surprising because the island is surrounded by sea water, and mangroves, which constitute the major source of the peat, grow in sea water. Elements can be classified into three groups based on their concentration in sea water. The first group, S, Ba, Na, Br, Rb, and Sr, which forms the most homogeneous group of all the elements, all have concentrations of greater than 0.01 ppm in sea water (Taylor and McLennan, 1985) that is uncontaminated by fresh water. The concentrations of this group of elements are similar from core to core and from one part of a single core to another part. Compared to the other elements, the range of concentrations in the dried peat is small. It is only 1 to 2 orders of magnitude compared to up to nine orders of magnitude for elements in other groups. Na, Rb, and Br are clearly associated with NaCl and are highly statistically correlated. Ba and Rb as well as S and Sr are also highly correlated in these samples, but many of the element pairs are not correlated. This is probably due to differing mechanisms of absorption from sea water that, together with small differences in overall concentration ranges, reduces the chance of correlations.

A second group of elements that have concentrations of less than 0.1 ppb in sea water show large differences in concentrations between samples of the same and other cores. These elements (Hg, Fe, Co, Hf, Ta, Th, W, Sc, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, and Au) are generally associated with the inorganic minerals (ash) found in peat. Except for Au and Hg, which are not correlated with any other elements, these elements are highly correlated with each other.

Elements with concentrations between 0.01 ppm and 0.1 ppb, such as As, Cr, Cs, Sb, Se, U, and Zn, belong to the third group in which differences in concentrations from place to place are not as pronounced as those of the second group but are more pronounced than those of the first group. Except for Se, these elements are highly correlated with each other.

U is also highly associated with Ba in group one. Data suggest that both elements are associated with both organic and inorganic portions of the peat to the same extent. The association is likely due to the size of these large lithophilic elements because the ions have different charges. Ba and Sr with similar charges do not correlate as well as Ba and U.

Correlation matrix analysis of individual cores was carried out to determine if each core followed the trends of the whole data set. In Vibracore TR1, As is more closely

correlated with Ba and U than in other cores. Sr, is highly correlated with Na and Br in Vibracore TR2. Sb, As, and Se appear to be associated with the sulfide fraction. Interestingly, Cr is also associated with these sulfide elements and more weakly associated with the lithophilic elements in this core. Correlations of these elements in other cores are generally similar to correlations determined on the whole data set.

The concentrations of elements in the Tobacco Range peat are strikingly similar to those in the Indonesian fresh water peats along the Batang Hari River in Sumatra (Cameron et al., 1989). Of course, the elements of the first group, namely S, Ba, Na, Br, and Sr, but not Rb, are significantly higher in the Tobacco Range peats than in the Indonesian peats, which suggests that they were largely added to the peat after the plants died and did not have a significant role in tissue building. Most of the average concentrations of the other elements are similar to the Indonesian peats within a factor of two. This may mean that the Tobacco Range peat like the Sumatra peat has a terrestrial source of elements brought to each deposit from volcanic dust and pumice which even today wash up on the shores periodically in large amounts.

These offshore islands, which are on limestone bedrock, now have no clear terrestrial source other than the volcanic dust and pumice mentioned above. Although there is no evidence that the limestone supporting the peat of Tobacco Range may have supplied the mangroves with groundwater from the continent via systems of increased porosity, we speculate that such a source could exist especially along the north-northeast-trending faults dipping to the southeast with recharge areas in the mountainous uplands of northern Belize and Yucatan (Miller and Macintyre, 1977). A recharge area may also lie in the flat low-lying northern part of the Yucatan Peninsula; Hanshaw and Back (1980) discussed that the Yucatan lacks stream channels even though there is a mean annual discharge of 8.6 million m^3 for each 1 km of the 1,100-km coastline. However, the editors of this volume (1995, personal communication) do not believe that groundwaters are present at Tobacco Range and state that waters in a cave 100 m below MSL off Columbus Cay to the north show no signs of groundwater, with salinities of normal seawater levels.

The presence of fresh ground water in the limestone of Tobacco Range from the continent would support the explanation of a terrestrial source of elements as the plant nutritive source and could be a partial explanation for the slumping of peat off the edge of the island. However, extensive measurements by the Littlers' research group throughout the Tobacco Range fracture zone over a three year period, including the deeper humic water seeps, showed no dilution by freshwater sources (M.and D. Littler, 1995, personal communication).

SUMMARY

Tobacco Range is an island of mangrove peat built on a limestone platform that was topographically high during the Late Pleistocene when the ocean regressed to the east beyond the present coral reef crest.

Exclusive mangrove peat accumulation kept up with sea level rise but not at an even pace. Mangroves grew faster when they were within the optimum range of nutrients governed by tidal range. Different plant communities took hold: *Avicennia* Open

Woodland with *Rhizophora*, unvegetated flats, *Rhizophora* woodland, *Rhizophora* scrub, and *Rhizophora* thicket. Such processes account for the heterogeneity of ash and trace element contents in the peat.

The geologic history also affects the composition of the peat. Volcanic eruptions on the mainland have significantly affected the nutrients available for plant growth, the ash content and the trace element distribution in the peat. There are similarities in elemental composition with the fresh water Sumatra peats which have a history of volcanic eruptions and these mangrove (salt water) peats, which suggests that volcanic ash and incorporation into biomass may be an important factor in the trace element distribution. Although there is no supporting evidence, it is also possible that the tilted fault blocks of the continent and the shelf could provide conduits for dissolved elements from the continental rocks that may still continue to reach the peat and mangroves as groundwater discharges in the Tobacco Range.

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Table 1. Proximate and ultimate analyses and sulfur forms of three samples of Tobacco Range peat (Dickerson Labs, Inc.)

Proximate Analysis	As Received	Dry Basis	Moisture & Ash Free Basis	Ultimate Analysis	As Received %	Dry Basis %	Sulfur Forms	As Received %	Dry Basis %
(a) Sample 5 at depth of about 1.3 meters at core site TR1									
% Moisture	30.78			Moisture	30.78		Pyritic	0.00	0.01
% Ash	21.79	31.78		Carbon	25.55	36.92	Sulfate	0.68	0.99
% Volatile	33.04	47.73	69.65	Hydrogen	2.52	3.64	Organic	2.07	2.97
% Fixed Carbon	14.39	20.79	30.35	Nitrogen	0.71	1.02	Total	2.75	3.97
				Chlorine	9.28	13.40			
				Sulfur	2.75	3.97			
Btu	4553	6578	9600	Ash	21.79	31.48			
				Oxygen (diff)	6.62	9.57			
% Sulfur	2.75	3.97							
(b) Sample 47 at depth of about 6 meters at core site TR5									
% Moisture	45.43			Moisture	45.43		Pyritic	0.00	0.01
% Ash	17.08	31.30		Carbon	21.43	39.27	Sulfate	0.41	0.76
% Volatile	26.84	49.20	71.61	Hydrogen	1.97	3.62	Organic	2.08	3.80
% Fixed Carbon	10.65	19.5	28.39	Nitrogen	0.35	0.65	Total	2.49	4.57
				Chlorine	6.67	12.22			
				Sulfur	2.49	4.57			
Btu	3734	6842	9960	Ash	17.08	31.3			
				Oxygen (diff)	4.58	8.37			
% Sulfur	2.49	4.57							
(c) Sample 31 at depth of about 5 meters at core site F									
% Moisture	89.13			Moisture			Pyritic	0.00	0.01
% Ash	3.33	30.60		Carbon	4.25	39.1	Sulfate	0.07	0.66
% Volatile	4.66	42.91	61.83	Hydrogen	10.39	3.79	Organic	0.49	4.46
% Fixed Carbon	2.88	26.49	38.17	Nitrogen	0.08	0.71	Total	0.56	5.13
				Chlorine					
				Sulfur	0.56	5.13			
Btu	756	6954	10020	Ash	3.33	30.60			
				Oxygen (diff)	81.39	20.67			
% Sulfur	0.56	5.13	7.40						

Table 2. Qualitative data for peat core samples located on cross section (fig. 3) listed from northwest to southeast along traverse line.

Core	Sample Number	Total Sulfur (%)	Ash (dry) (%)	pH	Lithology	Comments
TR5..............	72				muddy peat	Dark brown coarse fibers, sand pockets; mollusk shells, Thalassia.
	46	3.6	38.9	6.3	muddy peat	Red brown coarse fibers; reworked by the sea as in Sample 72.
	47	4.6	31.3		muddy peat	Dark brown coarse fibers.
	48	3.7	37.1	5.2	muddy peat	Dark brown coarse fibers.
	49	4.2	51.8	6.9	muddy peat	Dark brown fine fibers.
	50	4.3	32.1	5.9	muddy peat	Dark red brown, large wood fragments; mature.
	51	5	35.2	4.9	muddy peat	Dark red brown, large wood fragments; mature; with leaves.
	52	4.7	30.6	4.9	peat	Red brown fine fibers peat.
TR4.............	74				muddy peat	Dark brown coarse fiber peat, sand, Thalassia fragments.
	75				muddy peat	Dark brown coarse fiber peat and sand.
	76				muddy peat	Brown fine fibered peat.
	77				muddy peat over peaty mud	Dark brown organics over grey dense mud over watery mud, wood, and sand.
TR6.............	78				muddy peat	Dark brown gray; organic; water.
	44	4.6	24.6	5	peat	Medium brown, coarse fibered.
	80				peat	Brown; fine fibers.
	45	4.1	28.8	4.8	peat	Brown; fine fibers.
	81				muddy peat	Sandy.
TR2.............	82				peaty mud	Gray brown mud with sand fragments and shells. Reworked.
	22	4.3	28.8	4.9	peat	Fine fibered red brown; many mollusk shells. Reworked by sea.
	23	4.4	14.1	4.7	peat	Coarse fibers; red brown; prop roots; leaves. Mostly red mangrove.
	24	4.1	13	4.5	peat	Coarse fibers; red brown; prop roots; leaves. Mostly red mangrove.
	25	4.6	31	4.9	peat	Coarse fibers; red brown; prop roots; leaves. Mostly red mangrove.
	26	4.5	23.1	4.7	peat	Dark red brown fine fibers. Root mat.
	27	5.5	16.5	5.5	peat	Dark red brown fine fibers. Root mat.
	28	3.6	27.6	5.9	peat	Dark red brown fine fibers. Root mat.
	29	5.6	14.6	5.5	peat	Dark red brown fine fibers. Root mat.
	30	5.1	10.7	4.4	peat	Dark red brown fine fibers. Root mat.
	31	5.2	14.3	5.4	peat	Dark red brown fine fibers. Root mat.
	32	4.7	24.2	5.2	peat	Dark red brown fine fibers. Root mat.
	33	5.2	28.3	4.3	peat	Dark red brown fine G18fibers. Root mat.

Table 3. Elements in samples taken from cores along northwest-southeast traverse (fig. 2) listed by sample number (fig. 3). Averages for each element in each core are given. In cases where less than two data points are available for a given element in a given core the average could not be calculated and is indicated by ---.

Core	Sample No.	S (%)	Hg (ppm)	Ash (%)	pH	Fe (%)	Na (%)	As (ppm)	Ba (ppm)	Br (ppm)	Co (ppm)	Cr (ppm)
TR5	46	3.60	< 0.005	38.9	6.3	0.036	4.9	7.6	268	920	0.255	2.28
	48	3.70	< 0.005	37.1	5.2	0.947	3.6	28.4	495	711	2.58	33.2
	49	4.20	< 0.005	51.8	6.9	0.150	6.5	< 5	297	1210	0.82	8.1
	50	4.30	< 0.005	32.1	5.9	0.019	4.2	5.80	245	860	0.509	2.66
	51	5.00	< 0.005	35.2	4.9	0.552	5.2	8.7	461	1030	1.67	8.8
	52	4.70	< 0.005	30.6	4.4	0.735	3.6	7.0	457	648	11.5	14.6
	AVG TR5	4.25	---	37.6	5.6	0.406	4.67	11.4	372	890	2.89	11.6
TR6	44	4.60	< 0.005	24.6	5.0	0.089	4.8	7.9	317	1260	5.05	5.4
	45	4.10	< 0.005	28.8	4.8	0.276	4.8	< 5.0	150.	810	1.06	6.4
	AVG TR6	4.35	---	26.7	4.9	0.183	4.8	---	235	1055	3.08	5.90
TR2	22	4.30	< 0.005	28.8	4.9	0.153	7.5	19.3	258	1140	0.49	12.8
	23	4.40	< 0.005	14.1	4.7	0.138	5.9	16.1	486	861	0.47	12.8
	24	4.10	< 0.005	13.0	4.5	0.039	6.1	8.7	540	815	0.261	7.2
	25	4.60	< 0.005	30.2	4.9	0.081	7.4	< 4	558	1120	0.505	12.1
	26	4.50	< 0.005	23.1	4.7	0.222	7.1	7.2	480	959	0.62	19.6
	27	5.50	< 0.005	16.5	5.5	0.042	5.6	< 6	167	668	0.173	1.51
	28	3.60	< 0.005	27.6	5.9	0.037	12.1	< 6	274	1630	0.441	1.76
	29	5.60	< 0.005	14.6	5.5	0.419	7.4	< 4	346	926	0.80	11.5
	30	5.10	< 0.005	10.7	4.4	0.211	7.7	< 7	524	1000	0.87	4.79
	31	5.20	< 0.005	14.3	5.4	0.045	7.8	< 4	488	976	0.41	2.2
	32	4.70	< 0.005	24.2	5.2	0.100	10.5	6.9	81	1100	0.54	2.52
	33	5.20	< 0.005	28.3	4.3	0.107	7.8	5.4	113	964	0.50	1.85
	34	5.10	< 0.005	15.4	5.4	0.198	5.09	< 3	63	587	1.14	2.35
	AVG TR2	4.76	---	20.1	5.0	0.138	7.57	10.5	337	980	0.552	7.25
TR1	1	2.20	0.01	37.6	6.3	0.048	7.1	< 12	241	2140	0.200	6.40
	2	3.50	< 0.005	32.8	5.7	0.129	4.51	25.8	705	1270	0.722	10.7
	3	4.20	< 0.005	23.8	5.4	0.095	4.2	15.5	267	990	0.338	9.00
	4	4.20	< 0.005	27.2	5.6	0.031	4.8	< 5	386	1080	0.197	4.03
	6	1.40	< 0.005	27.7	4.9	0.067	4.2	< 8	730	980	0.282	8.9
	7	4.40	< 0.005	34.3	4.8	0.151	5.2	< 8	320	1190	0.359	11.9
	8	3.90	< 0.005	33.8	5.3	0.132	6.3	< 9	382	1470	0.379	11.3
	9	4.30	< 0.005	18.6	4.8	0.166	4.7	< 8	< 60	1140	0.531	19.1
	10	4.50	< 0.005	20.2	5.2	0.162	4.8	< 7	221	1030	0.410	18.1
	11	4.10	< 0.005	16.7	4.9	0.160	4.4	9.5	< 70	930	0.418	19.1
	12	4.60	< 0.005	19.7	5.1	0.204	3.7	< 7	477	810	0.46	20.4
	13	3.80	< 0.005	37.7	4.7	0.019	8.2	< 10	169	1530	0.144	2.91
	14	5.30	< 0.005	17.3	5.2	0.300	3.5	< 7	311	695	0.78	10.7
	15	5.00	< 0.005	22.0	5.1	0.170	3.4	< 8	463	860	0.727	5.94
	16	5.40	< 0.005	31.1	5.4	0.043	9.85	16.0	360	1100	0.73	3.33
	17	4.20	< 0.005	28.7	4.9	0.050	12.0	< 4	201	896	0.32	1.90
	18	2.40	< 0.005	17.4	5.9	0.269	6.2	6.5	58	625	1.43	5.71
	19	5.60	< 0.005	14.6	4.6	0.200	6.5	< 3	36	628	1.08	2.78
	20	5.30	< 0.005	26.7	4.4	0.896	7.1	< 3	50	687	2.45	13.3
	21	4.30	< 0.005	44.1	3.3	1.93	3.53	7.3	91	331	4.45	52.9
	AVG TR1	4.13	---	26.6	5.1	0.261	5.71	13.4	304	1017	0.822	11.9
A	4	4.20	0.010	48.1	3.90	1.60	6.54	9.5	130	617	5.13	43.4
J	47	3.80	< 0.005	69.5	5.60	3.41	3.25	23.1	190	334	11.1	95
	48	4.60	< 0.005	30.1	5.90	0.065	6.2	4.9	113	< 500	0.304	2.30
	49	5.10	0.010	33.0	5.30	0.157	5.4	4.4	324	< 500	0.66	5.99
	50	4.10	< 0.005	30.4	5.90	0.076	6.4	5.7	83	< 500	0.455	2.68
	51B	4.50	0.010	87.4	3.40	5.13	1.15	17.2	110	76.0	13.4	130
	AVG J	4.42	0.010	50.1	5.22	1.77	4.50	11.0	163	203	5.18	47

Table 3 (continued)

Core	Sample No.	Cs (ppm)	Hf (ppm)	Rb (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	W (ppm)	Zn (ppm)
TR5	46	0.029	< 0.04	1.33	0.44	0.86	165	0.025	0.0800	42	---	3.01
	48	2.12	0.97	29.4	1.60	2.77	318	0.312	2.50	63	---	15.5
	49	0.295	0.145	4.5	0.37	1.01	248	0.044	0.420	45	---	3.6
	50	0.048	0.044	1.14	0.19	1.11	90	0.017	0.110	38	---	2.14
	51	0.333	0.229	4.9	0.383	1.26	107	0.053	0.560	70	---	6.1
	52	0.64	0.466	8.0	0.60	1.24	108	0.114	1.30	66	---	13.4
	AVG TR5	0.573	0.371	8.13	0.597	1.38	175	0.093	0.828	54	---	7.13
TR6	44	0.281	0.16	4.4	0.329	1.45	116	0.048	0.370	49	---	5.9
	45	0.355	0.23	4.1	0.34	0.63	122	0.058	0.630	20.4	---	6.2
	AVG TR6	0.320	0.195	4.25	0.335	1.06	119	0.053	0.500	34.5	---	6.1
TR2	22	0.241	0.181	3.9	0.61	2.80	154	0.065	0.409	42	---	6.4
	23	0.172	0.130	3.0	0.67	3.25	113	0.032	0.32	76	---	5.7
	24	0.060	0.068	2.1	0.450	2.02	96	< 0.02	0.118	88	---	3.5
	25	0.170	0.107	3.5	0.58	3.04	168	0.035	0.241	92	---	5.0
	26	0.35	0.196	4.7	0.414	3.91	134	0.057	0.53	79	---	5.8
	27	< 0.01	0.095	< 1	0.185	1.08	141	< 0.02	0.041	28	---	2.15
	28	0.043	0.206	2.12	0.280	0.50	182	< 0.02	0.077	49	---	2.8
	29	0.602	0.323	10.2	0.55	1.56	128	0.100	0.90	56	---	9.8
	30	0.206	0.103	4.0	0.353	1.34	122	0.029	0.304	86	---	4.5
	31	0.026	0.025	< 2	0.22	1.22	133	< 0.02	0.087	80	---	3.0
	32	0.112	0.145	2.2	0.380	0.66	174	0.030	0.181	12.9	---	3.3
	33	0.070	0.062	1.5	0.272	0.78	166	0.017	0.164	17.3	---	2.00
	34	0.064	0.075	2.1	0.46	0.74	129	< 0.02	0.23	10.7	---	4.9
	AVG TR2	0.176	0.133	3.6	0.416	1.76	140	0.0456	0.277	55.2	---	4.53
TR1	1	0.149	0.106	3.15	0.85	1.09	167	0.040	0.278	35.9	---	5.9
	2	0.242	0.159	4.2	1.02	2.12	130	0.060	0.400	107	---	12.6
	3	0.157	0.449	3.3	0.319	1.53	102	0.029	0.284	39	---	4.7
	4	0.045	0.027	1.61	0.246	1.07	113	< 0.02	0.097	58	---	3.03
	6	0.093	0.101	1.9	0.396	1.80	96	< 0.02	0.190	111	---	3.9
	7	0.199	0.139	4.3	0.331	2.20	120	0.037	0.328	46	---	5.4
	8	0.167	0.124	3.1	0.268	2.56	114	0.036	0.292	58	---	4.45
	9	0.338	0.179	4.4	0.27	3.28	118	0.061	0.583	47	---	5.2
	10	0.228	0.165	4.3	0.180	3.16	135	0.046	0.47	31	---	5.3
	11	0.191	0.135	4.0	0.180	3.45	129	0.048	0.404	72	---	8.7
	12	0.237	0.174	3.3	0.220	3.53	124	0.040	0.454	72	---	9.5
	13	0.038	0.035	1.87	0.078	0.88	146	< 0.01	0.070	26.3	---	2.3
	14	0.64	0.284	9.0	0.439	1.44	116	0.112	0.783	46	---	5.5
	15	0.248	0.147	4.6	0.279	1.07	139	0.045	0.379	64	---	3.7
	16	0.120	0.092	3.5	0.21	1.02	129	< 0.04	0.189	75	< 4	2.8
	17	0.063	0.071	2.1	0.160	0.67	182	< 0.02	0.138	36	---	2.9
	18	0.363	0.247	3.3	0.34	0.69	149	0.060	0.631	7.8	---	5.5
	19	0.080	0.083	1.7	0.334	0.60	115	< 0.02	0.200	5.4	---	7.8
	20	1.10	0.660	12.0	0.420	0.67	143	0.170	1.58	6.3	---	14.4
	21	4.32	2.87	35.6	0.72	< 2	129	0.701	8.2	7.9	---	39.8
	AVG TR1	0.450	0.314	5.59	0.362	1.73	129	0.106	0.797	47.7	---	7.7
A	4	2.31	1.92	33.2	1.06	< 1	131	0.414	3.53	17.6	---	28.7
J	47	5.83	4.27	68	2.33	1.6	120	0.94	10.1	26.9	---	49.1
	48	0.100	0.078	2.4	0.251	---	115	< 0.03	0.166	19.2	---	2.8
	49	0.245	0.183	4.2	0.49	---	103	0.038	0.320	56	---	2.1
	50	0.089	0.226	1.2	0.187	---	103	< 0.03	0.170	14.5	---	2.1
	51B	9.2	6.7	80	1.26	< 1	95	1.55	18.4	2.61	---	71
	AVG J	3.09	2.30	31.2	0.906	---	107	0.826	5.73	23.7	---	25.4

Table 3 (continued)

Core	Sample No.	Sc (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Au (ppb)
TR5	46	0.122	---	2.1	---	< 0.2	0.017	0.007	< 0.1	< 0.08	< 25
	48	3.80	3.7	13.7	< 3	0.88	0.240	0.158	0.42	0.122	< 17
	49	0.663	< 2	4.7	---	< 0.3	0.078	0.045	< 0.2	< 0.07	< 30
	50	0.142	---	3.2	---	< 0.2	0.034	0.022	< 0.1	< 0.06	< 18
	51	0.774	---	6.0	---	< 0.4	0.078	0.054	0.34	< 0.1	< 20
	52	1.71	2.5	11.4	< 4	0.76	0.220	0.148	0.65	< 0.1	< 16
	AVG TR5	1.20	3.10	6.8	---	0.82	0.111	0.0730	0.47	---	---
TR6	44	0.548	< 2	6.0	---	< 0.2	0.059	0.042	< 0.2	< 0.08	< 25
	45	0.697	1.4	3.73	< 3	0.32	0.068	0.052	0.20	< 0.02	< 23
	AVG TR6	0.623	---	4.85	---	---	0.0635	0.047	---	---	---
	22	0.771	---	< 6	---	0.29	0.076	0.050	< 0.4	< 0.5	< 25
	23	0.628	---	< 6	---	< 0.2	0.064	0.040	< 0.5	< 0.8	< 19
	24	0.222	---	< 7	---	< 0.2	0.030	0.012	0.18	< 1	< 19
	25	0.416	---	< 5	---	< 0.2	0.037	0.030	< 0.1	< 0.9	< 19
	26	0.90	---	< 7	---	0.3	0.083	0.065	0.44	< 0.8	< 23
	27	0.058	---	< 3	< 2	< 0.1	0.022	0.014	< 0.1	< 0.3	< 14
	28	0.106	---	< 0.9	---	< 0.2	0.012	< 0.005	< 0.2	< 0.5	< 30
	29	1.35	---	< 6	< 3	0.45	0.084	0.063	< 0.2	< 0.5	< 19
	30	0.463	---	< 7	< 4	< 0.2	0.050	0.033	< 0.1	< 0.9	< 25
	31	0.110	---	< 4	< 3	< 0.2	0.026	0.016	< 0.1	< 0.8	< 18
	32	0.197	---	1.21	< 3	< 0.2	0.024	0.014	< 0.2	< 0.2	< 31
	33	0.225	< 0.7	1.5	< 2	0.24	0.028	0.018	< 0.1	< 0.3	< 18
	34	0.278	< 0.7	0.78	< 2	< 0.2	0.036	0.026	0.24	< 0.1	< 17
	AVG TR2	0.444	---	1.16	---	0.31	0.044	0.032	0.29	---	---
TR1	1	0.440	< 0.6	2.56	---	< 0.4	0.050	0.032	< 0.2	< 0.4	< 32
	2	0.651	< 7	6.2	---	< 0.4	0.056	0.040	< 0.2	< 0.2	< 23
	3	0.478	< 1	3.1	---	< 0.2	0.045	0.031	< 0.2	< 0.06	< 20
	4	0.161	---	3.1	---	< 0.3	< 0.03	0.013	< 0.2	< 0.1	< 20
	6	0.344	< 3	5.3	---	< 0.4	0.036	0.021	< 0.1	< 0.2	< 30
	7	0.587	2	3.7	---	< 0.3	0.049	0.035	< 0.2	< 0.04	< 22
	8	0.523	1.7	3.8	---	< 0.3	0.061	0.041	0.33	< 0.08	< 23
	9	0.999	2.8	5.2	---	0.41	0.103	0.070	< 0.5	< 0.08	< 19
	10	0.913	3.1	5.2	< 2	0.39	0.117	0.074	0.37	0.055	< 18
	11	0.838	4.6	6.0	---	< 0.5	0.107	0.081	0.23	< 0.1	< 19
	12	0.936	4.2	6.2	---	0.38	0.121	0.080	0.26	< 0.09	< 16
	13	0.132	2.1	1.59	---	< 0.3	0.027	0.016	< 0.2	< 0.05	< 30
	14	1.23	3.7	5.6	---	0.44	0.083	0.062	< 0.2	< 0.05	< 18
	15	0.619	3.9	6.1	---	< 0.3	0.054	0.036	< 0.2	< 0.09	< 18
	16	0.316	---	< 4	---	< 0.1	0.036	0.026	< 0.2	< 0.1	< 14
	17	0.189	---	< 2	---	< 0.2	0.027	0.010	< 0.1	< 0.5	< 21
	18	0.846	2.06	4.36	< 4	0.49	0.119	0.069	0.19	< 0.2	< 16
	19	0.217	< 0.9	1.38	< 3	< 0.2	0.027	0.018	< 0.2	< 0.2	< 23
	20	1.86	3.41	5.5	< 4	0.65	0.152	0.107	0.54	0.120	< 17
	21	8.70	18.7	33.9	14.5	4.49	0.89	0.586	2.48	0.28	< 16
	AVG TR1	1.05	4.38	6.06	---	1.04	0.114	0.073	0.631	0.152	---
A	4	4.95	13.6	19.8	< 19	2.73	0.556	0.366	1.54	0.201	< 18
J	47	12.5	30.8	50	< 25	7.4	1.51	0.993	4.19	0.544	< 8
	48	0.204	2.05	1.50	---	< 0.2	0.022	0.022	< 0.08	< 0.04	5.9
	49	0.501	5.08	3.4	---	< 0.2	0.054	0.037	0.14	< 0.1	< 5
	50	0.260	1.89	1.76	---	< 0.2	0.033	0.019	< 0.08	< 0.02	< 4
	51B	21.2	61.2	103	< 30	12.1	2.42	1.60	6.7	0.850	< 8
	AVG J	6.93	20.2	31.3	---	9.75	0.802	0.534	3.68	0.695	---

Table 3 (continued)

Core	Sample No.	S (%)	Hg (ppm)	Ash (%)	pH	Fe (%)	Na (%)	As (ppm)	Ba (ppm)	Br (ppm)	Co (ppm)	Cr (ppm)
I	38	4.40	0.02	28.5	4.50	0.121	6.3	25.4	323	< 700	0.347	6.7
	39	4.00	< 0.005	25.1	5.40	0.052	4.25	10.2	354	< 600	0.236	5.98
	40	4.60	< 0.005	31.9	5.30	0.356	5.11	7.2	222	< 700	0.92	35.8
	41	4.40	< 0.005	31.4	5.60	0.079	6.6	6.4	177	< 600	0.249	4.02
	42	5.20	0.02	33.6	5.50	0.102	5.4	5.5	359	< 500	0.68	5.6
	43	4.00	0.02	30.9	5.70	0.057	7.9	< 5	183	< 700	0.326	3.06
	44	3.80	< 0.005	35.5	4.00	0.072	11.0	9.0	270	1160	0.31	3.93
	AVG I	4.34	0.02	31.0	5.14	0.120	6.64	10.5	269	---	0.440	9.30
F	28	4.00	< 0.005	26.3	5.60	0.089	4.75	13.7	298	< 600	0.365	6.26
	29	4.20	< 0.005	37.5	5.60	0.204	8.7	7.5	330	1140	0.517	22.2
	30	4.30	0.010	34.8	5.70	0.043	6.0	5.4	118	< 600	0.154	2.78
	32	4.30	< 0.005	36.1	5.40	0.185	8.8	7.0	290	990	0.622	7.7
	33	3.80	< 0.005	33.8	5.50	0.060	7.24	5.2	260	< 600	0.312	2.66
	34	4.00	< 0.005	32.7	5.40	0.137	7.6	4.8	110	< 600	0.629	6.4
	35	4.00	< 0.005	41.4	5.10	1.09	8.1	6.1	<150	784	4.73	28.8
	AVG F	4.09	---	34.7	5.47	0.260	7.30	7.14	235	957	1.05	11.0
E	26A	2.70	< 0.005	73.1	7.30	2.52	3.5	22.9	140	314	7.70	75
D	18	4.00	< 0.005	31.2	6.70	0.078	5.5	6.5	290	< 600	0.309	7.6
	19	4.00	< 0.005	32.4	6.70	0.102	6.7	5.0	284	< 600	0.341	12.0
	20	4.10	< 0.005	32.7	7.20	0.036	6.8	5.3	148	< 600	0.122	3.12
	21	4.40	< 0.005	35.3	7.20	0.032	7.4	< 2	250	< 700	0.212	3.0
	22	4.00	< 0.005	26.3	6.30	0.024	9.6	< 3	124	< 700	0.419	1.16
	23	3.70	< 0.005	32.0	7.00	0.035	6.8	2.7	196	< 600	0.209	2.76
	24	5.00	0.03	29.1	6.10	0.045	6.3	< 2	21	< 500	0.384	2.49
	AVG D	4.17	---	31.3	6.74	0.0503	7.01	4.88	187	---	0.284	4.60
B	5	0.0800	< 0.005	68.8	7.50	0.140	4.18	3.9	160	621	0.275	9.9
	6	3.30	< 0.005	34.1	6.60	0.127	6.9	8.8	300	< 800	0.288	10.0
	7	3.80	< 0.005	31.6	6.40	0.072	6.2	3.4	270	< 800	0.248	6.14
	8	4.50	< 0.005	31.0	6.50	0.040	6.4	4.8	51	< 600	0.148	2.62
	9	4.20	< 0.005	37.2	6.50	0.040	8.2	< 2	300.	1010	0.335	3.45
	10	3.80	< 0.005	28.8	7.00	0.027	7.0	3.7	101	< 600	0.164	1.73
	11	5.10	< 0.005	43.0	7.40	0.319	7.0	3.2	< 220	783	2.08	6.7
	12	5.20	< 0.005	46.2	6.40	0.88	9.8	< 2	< 190	940	2.55	14.0
	13	4.20	< 0.005	80.9	3.80	4.33	2.06	21.1	120	189	11.0	94.7
	AVG B	3.80	---	44.6	6.46	0.664	6.42	6.97	192	708	1.89	16.6
TR3	35	6.00	< 0.005	15.2	4.5	0.032	6.6	7.8	507	962	0.331	4.67
	36	5.00	< 0.005	16.0	5.7	0.058	5.8	12.8	400	1160	0.714	9.0
	37	5.60	< 0.005	21.3	5.7	0.069	6.1	< 7	222	787	0.239	2.47
	38	5.50	< 0.005	23.8	5.2	0.115	5.3	9.2	107	769	0.33	6.81
	39	6.00	< 0.005	24.5	5.6	0.079	7.6	< 4	161	1010	0.355	4.98
	40	5.00	< 0.005	5.8	5.8	0.053	6.1	5.6	398	866	0.50	3.1
	41	5.20	< 0.005	22.9	5.7	0.087	3.5	< 9	146	647	1.69	4.39
	42	5.00	< 0.005	70.9	3.6	3.13	1.35	17.6	92	213	8.39	87.9
	43	4.10	< 0.005	78.8	3.1	4.32	0.76	18.2	84	94	9.28	104
	AVG TR3	5.27	---	31.0	5.0	0.882	4.80	11.9	236	723	2.43	24.8
C	15	0.790	< 0.005	45.8	7.60	0.061	7.0	8.5	< 210	940	0.247	4.39
	16	0.840	< 0.005	49.8	7.60	0.064	4.29	6.5	170	573	0.195	3.68
	17	3.00	< 0.005	35.4	7.70	0.061	7.5	4.7	280	850	0.279	7.4
	AVG C	1.54	---	43.7	7.63	0.062	6.27	6.57	225	787	0.240	5.17
	AVG All	4.25	0.0156	32.6	5.50	0.443	6.10	9.81	264	884	1.53	14.8

Table 3 (continued)

Core	Sample No.	Cs (ppm)	Hf (ppm)	Rb (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	W (ppm)	Zn (ppm)
I	38	0.163	0.130	2.8	0.94	---	100	0.052	0.304	60	---	3.3
	39	0.106	0.063	2.4	0.423	---	109	0.029	0.198	61	---	2.1
	40	0.95	0.476	10.4	0.38	---	113	0.157	1.45	34	---	9.8
	41	0.086	0.081	1.54	0.262	---	116	0.026	0.157	31.7	---	2.43
	42	0.224	0.14	3.4	0.286	---	108	0.048	0.34	62	---	2.3
	43	0.077	0.067	2.6	0.103	---	124	< 0.03	0.196	33.4	---	2.1
	44	0.067	< 0.2	< 3	0.60	< 0.8	118	< 0.04	0.120	72	---	< 2
	AVG I	0.239	0.160	3.78	0.427	---	113	0.0630	0.389	50.6	---	3.67
F	28	0.155	0.104	1.4	0.326	---	144	0.048	0.264	54	---	2.1
	29	0.303	0.186	5.6	0.336	2.4	133	0.064	0.53	67	---	4.8
	30	0.027	< 0.1	1.8	0.202	---	134	< 0.03	0.126	19.4	---	2.0
	32	0.414	0.206	6.5	0.384	< 0.7	134	0.067	0.466	49	---	3.9
	33	0.069	0.053	1.5	0.180	---	110	< 0.04	0.204	43.9	---	3.3
	34	0.146	0.163	2.8	0.219	---	109	0.051	0.324	19.5	---	4.9
	35	1.59	1.31	14.8	0.52	< 0.7	130	0.269	2.93	15.2	---	28.0
	AVG F	0.388	0.336	4.94	0.310	---	126	0.100	0.687	38.1	---	7.0
E	26A	4.28	2.50	55	2.40	< 1	790	0.72	5.9	12.7	---	37.9
D	18	0.095	0.075	< 4	0.277	---	201	0.025	0.193	53	---	2.3
	19	0.184	0.143	2.9	0.237	---	269	0.046	0.277	47	---	9.7
	20	0.036	0.064	< 1	< 0.1	---	224	< 0.03	0.142	25.5	---	2.1
	21	0.063	< 0.05	< 3	0.104	---	245	0.031	0.117	41	---	2.4
	22	0.027	0.087	1.2	0.078	---	150	< 0.03	0.066	21.5	---	3.5
	23	0.050	0.075	< 1	0.114	---	252	< 0.03	0.103	35.7	---	5.2
	24	0.043	0.045	< 2	0.093	---	186	< 0.04	0.093	2.71	---	6.5
	AVG D	0.071	0.081	2.0	0.150	---	219	0.034	0.141	32.4	---	4.53
B	5	0.73	0.442	16.8	0.30	< 0.5	3260	0.109	1.56	7.9	---	8.3
	6	0.182	0.144	< 4	0.216	---	304	0.045	0.352	26.3	---	5.4
	7	0.069	0.083	2.8	0.192	---	202	< 0.03	0.182	39.1	---	6.4
	8	0.034	0.071	2.0	0.117	---	160	< 0.03	0.092	9.0	---	2.3
	9	0.105	0.089	< 3	0.205	< 0.6	185	< 0.04	0.177	67	---	2.4
	10	0.018	0.096	2.0	0.110	---	202	< 0.03	0.061	18.1	---	2.6
	11	0.234	0.234	< 5	0.179	< 0.7	250	0.039	0.50	14.8	---	8.1
	12	0.447	0.57	7.4	0.25	< 0.7	207	0.107	1.14	14.6	---	13.6
	13	7.6	5.26	61	2.78	1.8	113	1.26	14.2	7.4	---	61.6
	AVG B	1.05	0.775	15.4	0.487	---	547	0.313	2.03	22.7	---	12.3
TR3	35	0.041	0.045	2.0	0.336	1.83	139	0.020	0.095	83	---	2.2
	36	0.202	0.180	3.4	0.214	1.86	145	0.050	0.412	66	---	2.9
	37	< 0.01	0.145	< 2	0.185	1.08	137	< 0.02	0.074	37	---	2.10
	38	0.119	0.187	2.3	0.160	1.68	121	0.030	0.258	18.0	---	2.99
	39	0.051	0.101	2.3	0.21	1.63	120	< 0.04	0.131	25.4	---	2.69
	40	< 0.05	0.039	1.5	0.197	1.23	118	< 0.02	0.095	62	---	5.8
	41	< 0.03	0.169	< 3	0.234	0.73	78	< 0.02	0.079	19.2	---	3.1
	42	7.42	5.28	50.1	2.14	0.93	67	1.28	14.8	2.8	---	64
	43	8.1	6.15	56	1.26	0.73	89	1.39	16.6	2.6	---	66
	AVG TR3	2.66	1.37	16.8	0.548	1.30	113	0.56	3.62	35	---	16.9
C	15	0.079	0.064	2.1	0.49	< 0.6	1290	0.037	0.117	36	---	2.2
	16	0.046	0.074	1.6	0.229	0.58	1820	< 0.03	0.107	31.8	---	2.5
	17	0.083	0.073	2.1	0.41	< 0.8	332	< 0.04	0.147	64	---	3.1
	AVG C	0.069	0.070	1.9	0.377	---	1143	---	0.127	44.0	---	2.6
	AVG All	0.787	0.571	9.46	0.466	1.59	219	0.194	1.37	41.2	---	9.38

Table 3 (continued)

Core	Sample No.	Sc (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Au (ppb)
I	38	0.407	4.77	3.3	---	< 0.2	0.045	0.032	< 0.1	< 0.2	< 5
	39	0.266	4.76	3.1	< 0.2	< 0.2	0.029	0.020	< 0.4	< 0.2	< 4
	40	2.16	8.6	10.3	< 2	1.19	0.278	0.184	0.83	0.094	9.6
	41	0.199	2.63	1.67	---	< 0.2	0.031	0.020	< 0.3	< 0.07	< 6
	42	0.497	5.48	3.7	---	< 0.2	0.059	0.036	0.16	< 0.1	< 5
	43	0.227	3.25	1.70	< 0.6	< 0.3	0.0360	0.0190	< 0.0900	< 0.0700	< 5
	44	0.157	4.51	< 5	< 30	< 0.2	0.041	0.017	< 0.6	< 0.03	< 15
	AVG I	0.560	4.87	3.92	---	---	0.0743	0.0463	0.495	---	---
F	28	0.357	3.91	3.3	---	< 0.2	0.047	0.036	0.15	< 0.1	< 4
	29	0.82	5.00	< 5	< 12	< 0.2	0.108	0.074	< 0.6	0.031	< 14
	30	0.113	2.22	1.75	---	< 0.2	0.027	0.020	< 0.08	< 0.05	< 4
	32	0.75	4.42	< 5	< 14	0.18	0.055	0.0454	< 0.7	< 0.02	< 13
	33	0.167	3.94	2.65	---	< 0.2	0.031	0.022	< 0.1	< 0.1	< 5
	34	0.397	2.52	2.1	< 0.3	< 0.2	0.048	0.031	0.17	< 0.04	< 4
	35	4.04	11.6	17.7	< 18	2.26	0.454	0.307	1.23	0.193	< 12
	AVG F	0.949	4.84	5.56	---	1.24	0.110	0.0770	0.507	0.111	---
E	26A	7.64	18.7	28.3	< 12	3.74	0.780	0.516	2.00	0.283	< 7
D	18	0.276	3.47	2.5	---	< 0.2	0.043	0.019	< 0.09	< 0.1	< 4
	19	0.460	3.66	3.0	---	< 0.2	0.053	0.040	0.18	< 0.1	< 4
	20	0.131	2.07	1.3	---	< 0.2	0.038	0.020	< 0.08	< 0.07	< 5
	21	0.133	2.91	1.6	< 0.6	< 0.2	0.019	< 0.005	< 0.09	< 0.1	< 5
	22	0.048	1.67	0.97	< 1.1	< 0.2	0.016	0.017	< 0.09	< 0.06	< 5
	23	0.134	2.63	1.53	---	< 0.2	0.032	0.021	< 0.08	< 0.1	6.7
	24	0.098	1.27	1.28	< 2	< 0.1	0.021	< 0.007	0.14	< 0.009	< 4
	AVG D	0.182	2.54	1.74	---	---	0.0317	0.0234	0.160	---	---
B	5	0.81	5.03	6.5	< 40	0.78	0.145	0.100	0.51	0.066	< 10
	6	0.527	3.10	2.9	< 4	0.28	0.084	0.044	0.16	< 0.08	< 4
	7	0.258	2.56	2.2	< 0.3	< 0.2	0.034	0.033	< 0.09	< 0.1	< 4
	8	0.145	1.00	0.97	< 0.3	< 0.1	0.027	< 0.02	< 0.2	< 0.03	< 4
	9	0.26	3.35	< 3	< 26	< 0.2	0.035	0.022	< 0.7	< 0.03	< 14
	10	0.065	1.29	0.91	---	< 0.2	0.018	< 0.009	0.14	< 0.06	< 4
	11	0.65	1.84	2.1	< 23	0.22	0.075	0.041	< 0.5	0.058	< 14
	12	1.39	3.05	4.6	< 28	0.64	0.155	0.099	1.3	0.079	< 14
	13	14.1	33.9	59.9	< 30	7.60	1.52	1.04	4.34	0.549	11
	AVG B	2.02	6.11	10.0	---	1.90	0.233	0.197	1.28	0.188	---
TR3	35	0.157	---	< 3	---	< 0.3	0.019	< 0.01	< 0.2	< 0.8	< 27
	36	0.574	---	2.5	---	< 0.3	0.064	0.044	0.22	< 0.6	< 18
	37	0.083	---	< 2	---	< 0.2	0.022	0.014	< 0.1	< 0.3	< 16
	38	0.335	---	< 3	< 3	0.16	0.037	0.027	< 0.1	< 0.3	< 19
	39	0.169	< 1	< 2	< 2	< 0.3	0.023	0.016	< 0.1	< 0.3	< 17
	40	0.087	---	< 5	---	< 0.2	0.015	0.017	< 0.2	< 0.6	< 17
	41	0.227	1.70	2.3	< 2.10	< 0.3	0.027	0.017	< 0.2	< 0.04	< 21
	42	13.9	32.5	57.6	19.9	6.71	1.37	0.992	3.76	0.56	< 10
	43	18.1	45.7	78.5	25.7	9.2	1.80	1.23	4.9	0.71	< 4
	AVG TR3	3.74	26.6	35.2	22.8	5.35	0.375	0.295	2.97	0.64	---
C	15	0.18	2.68	< 3	< 16	< 0.1	0.041	0.030	< 0.5	< 0.01	< 14
	16	0.126	2.50	< 2	< 15	< 0.1	0.034	0.023	< 0.4	< 0.02	< 11
	17	0.211	3.75	< 3	< 10	< 0.2	0.030	0.025	< 0.5	< 0.02	< 14
	AVG C	0.173	3.00	---	---	---	0.0350	0.0260	---	---	---
	AVG All	1.63	7.30	9.89	20.0	2.26	0.179	0.128	1.16	0.281	8.3

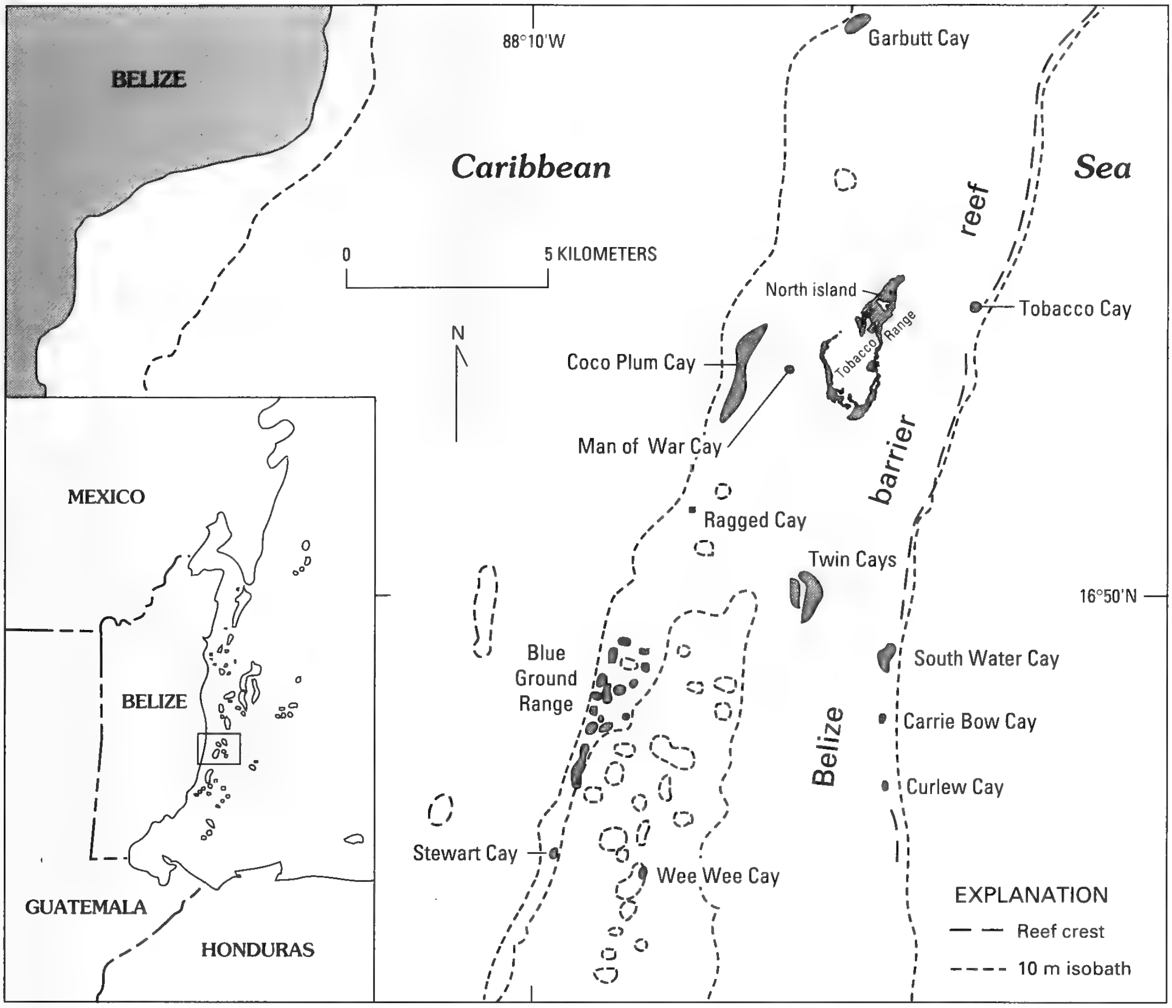


Figure 1. Location of Tobacco Range on the Belize barrier reef. Taken from Woodroffe (1995, this volume)

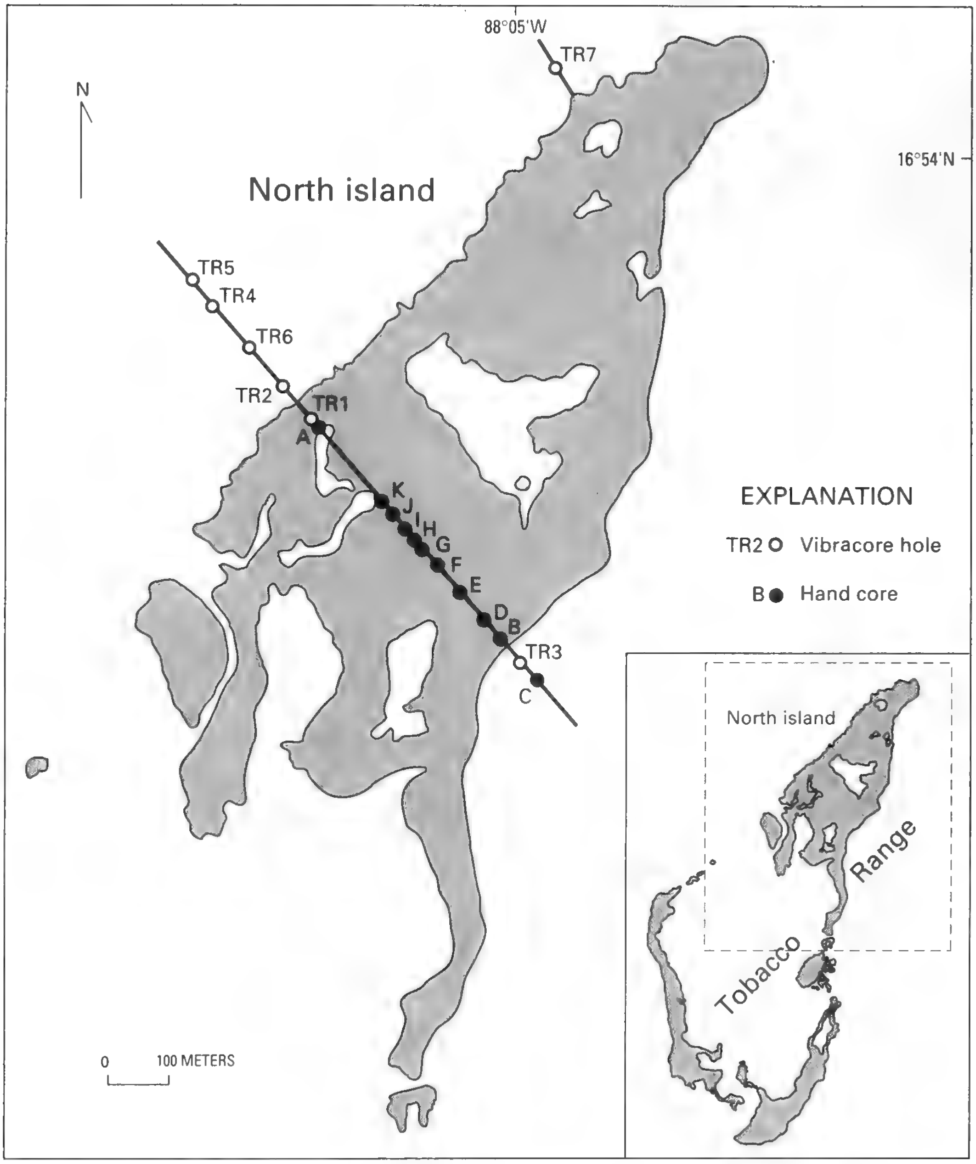


Figure 2. Northwest-southeast traverse across the north island of Tobacco Range showing location of cores. Taken from Macintyre et al. (1995, this volume)

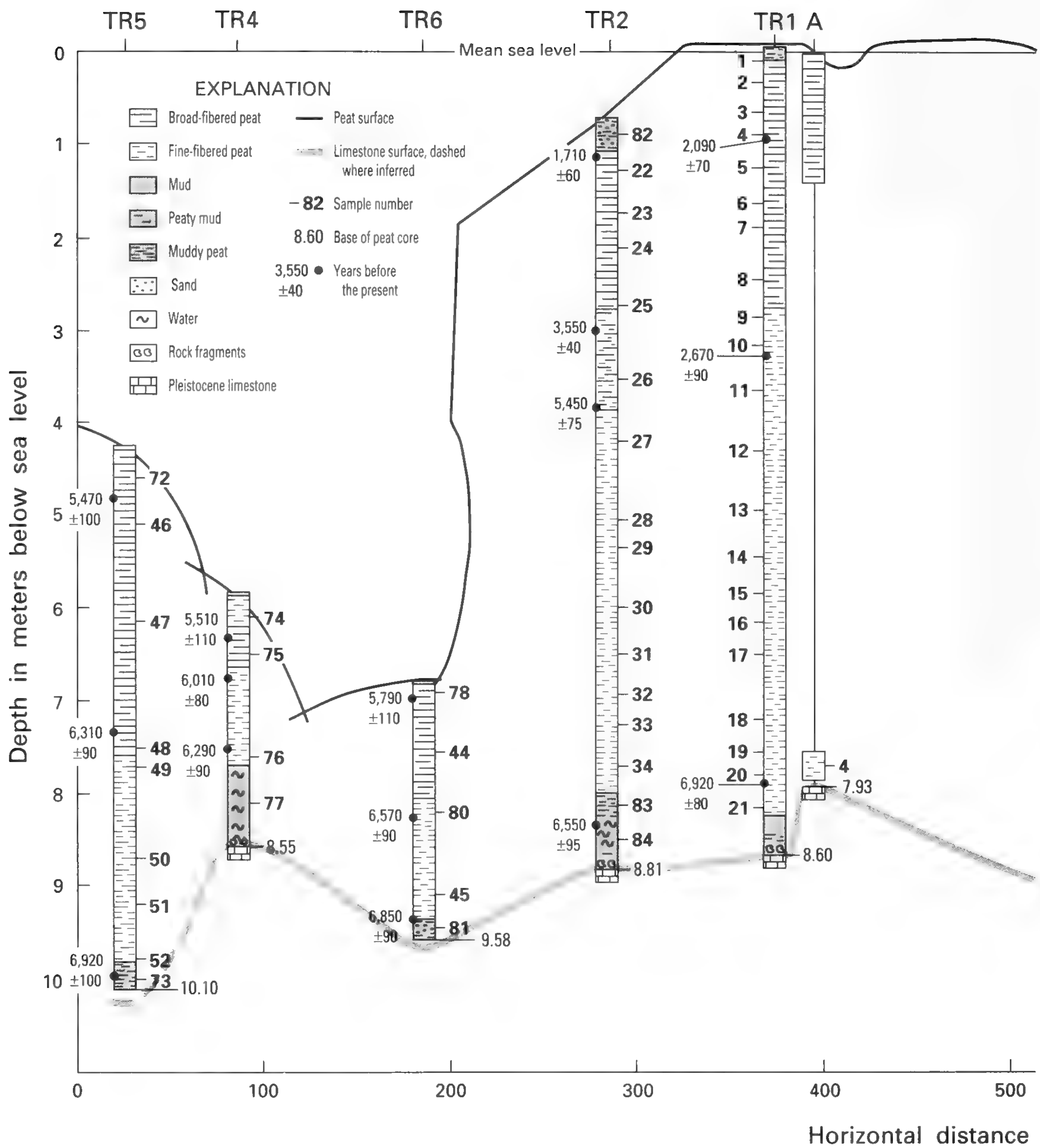
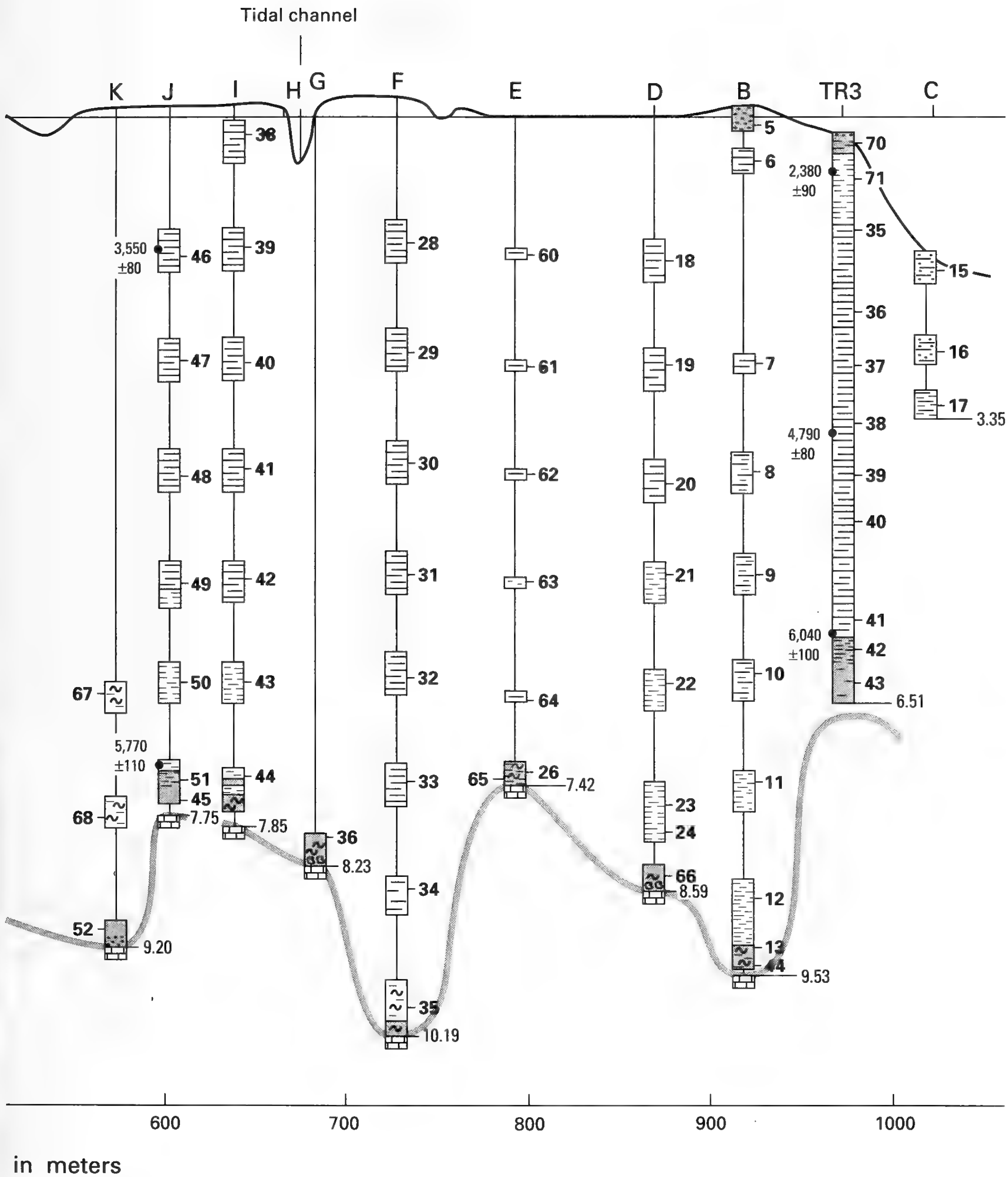


Figure 3. Cross section through the northwest-southeast traverse of Tobacco Range. Taken from Macintyre et al. (1995, this volume)


Tidal channel
K
J
I
H
G
F
E
D
B
TR3
C
3,550 ±80
2,380 ±90
4,790 ±80
6,040 ±100
5,770 ±110
9.20
7.75
7.85
8.23
10.19
7.42
8.59
9.53
6.51
3.35
600
700
800
900
1000
in meters

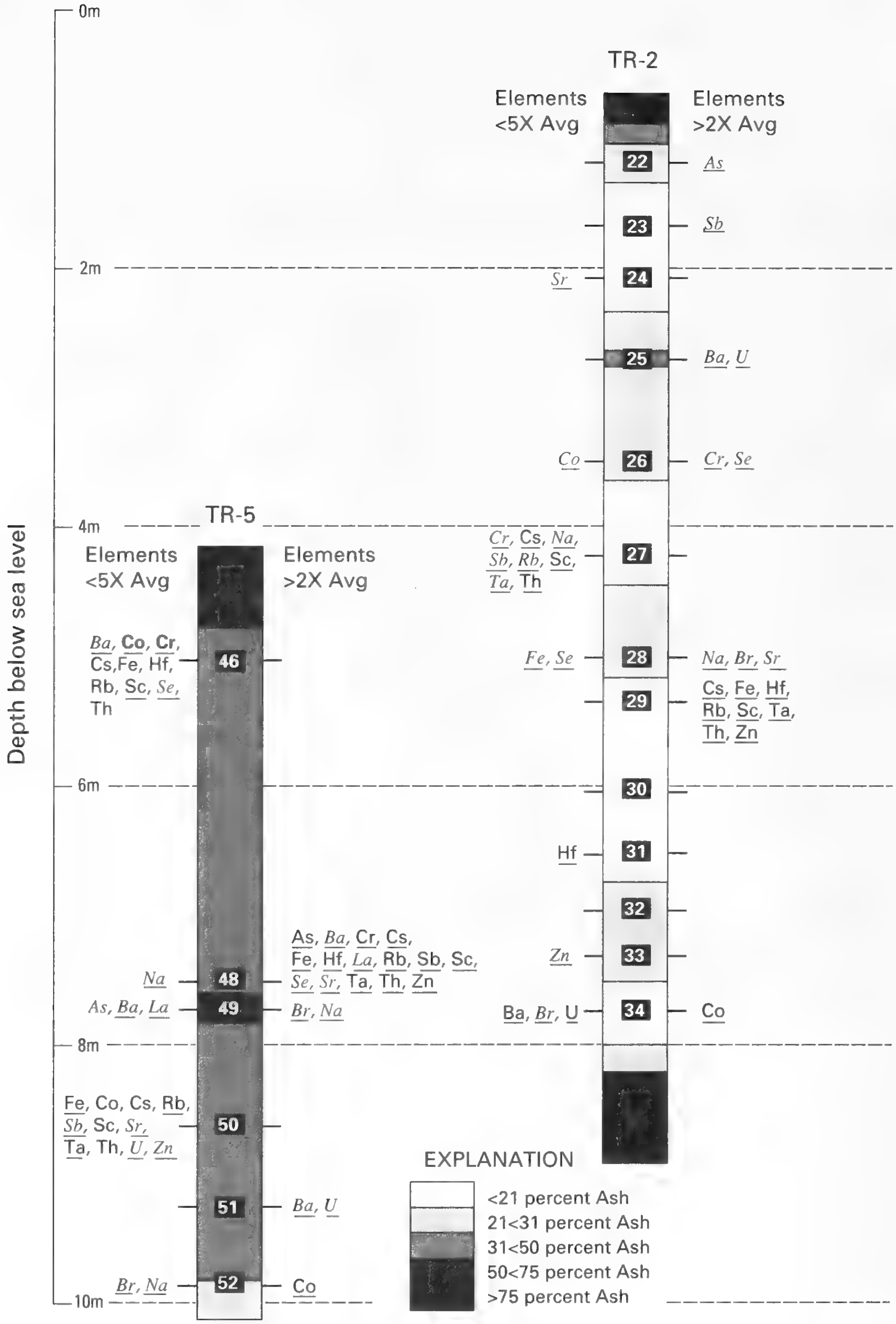


Figure 4. Ash and element distribution in cores TR5 and TR2. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores TR5 and TR2. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core.

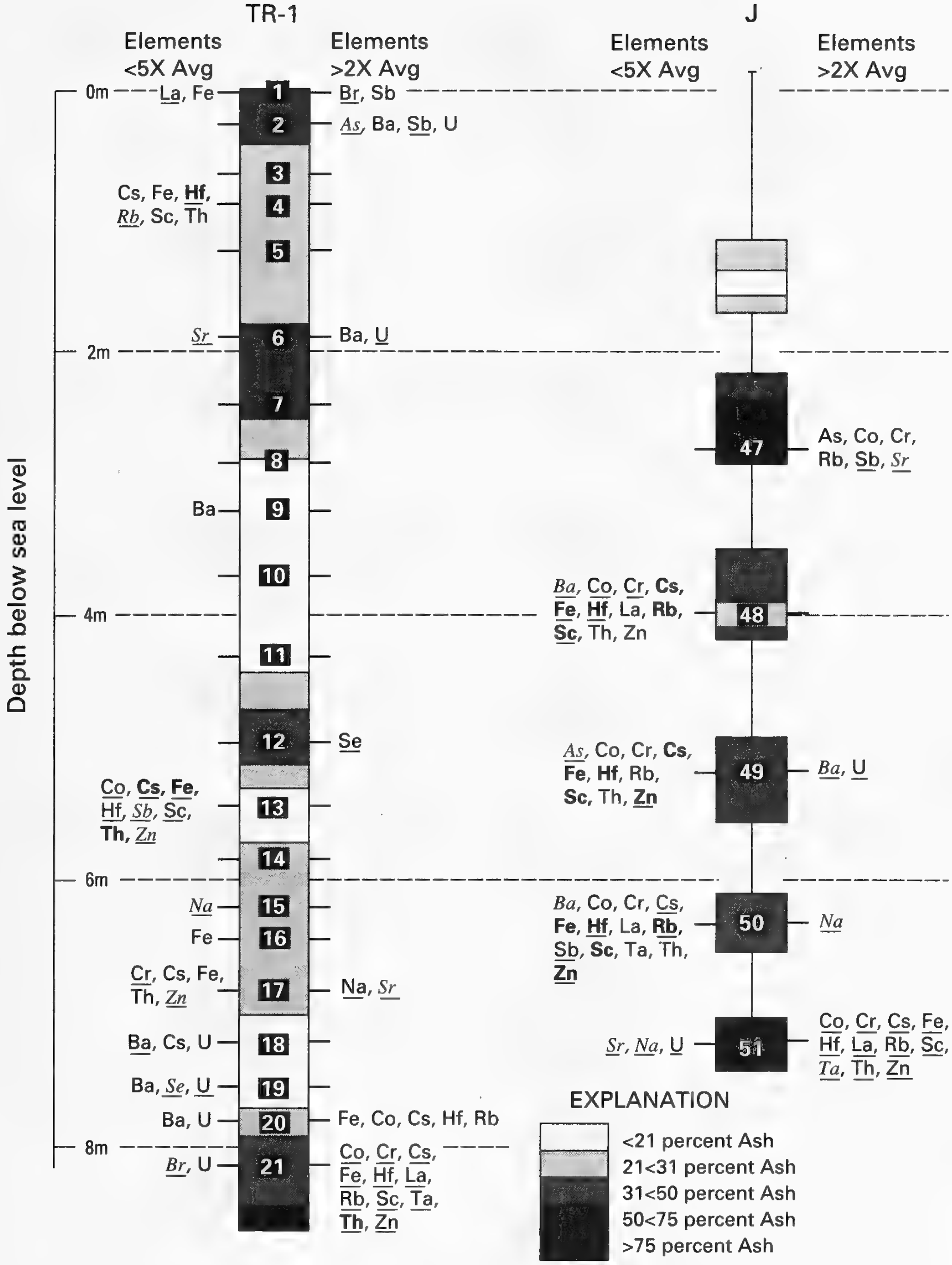


Figure 5. Ash and element distribution in cores TR1 and J. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores TR1 and J. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core. Elements in bold are greater or less than ten times the average.

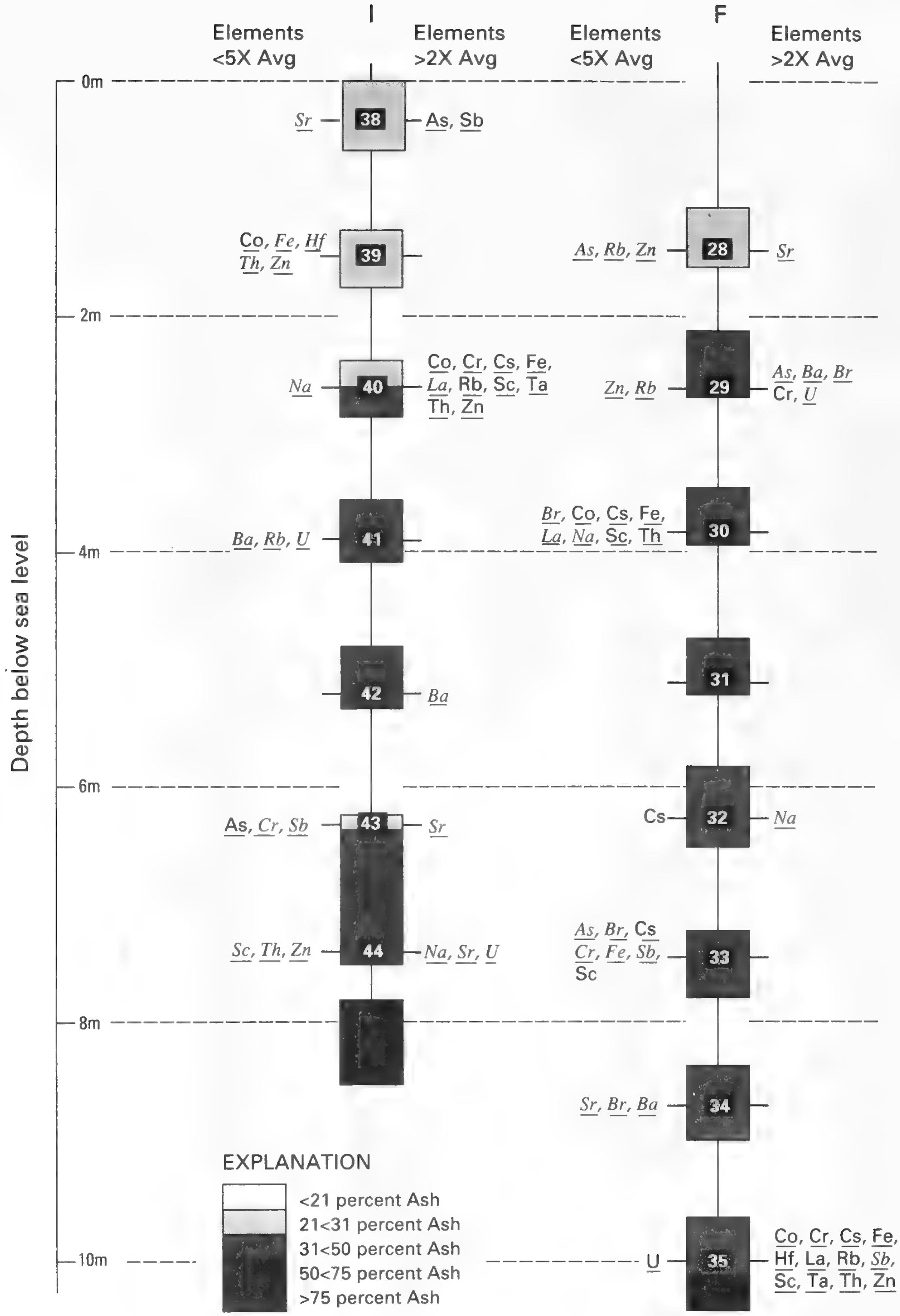


Figure 6. Ash and element distribution in cores I and F. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores I and F. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core.

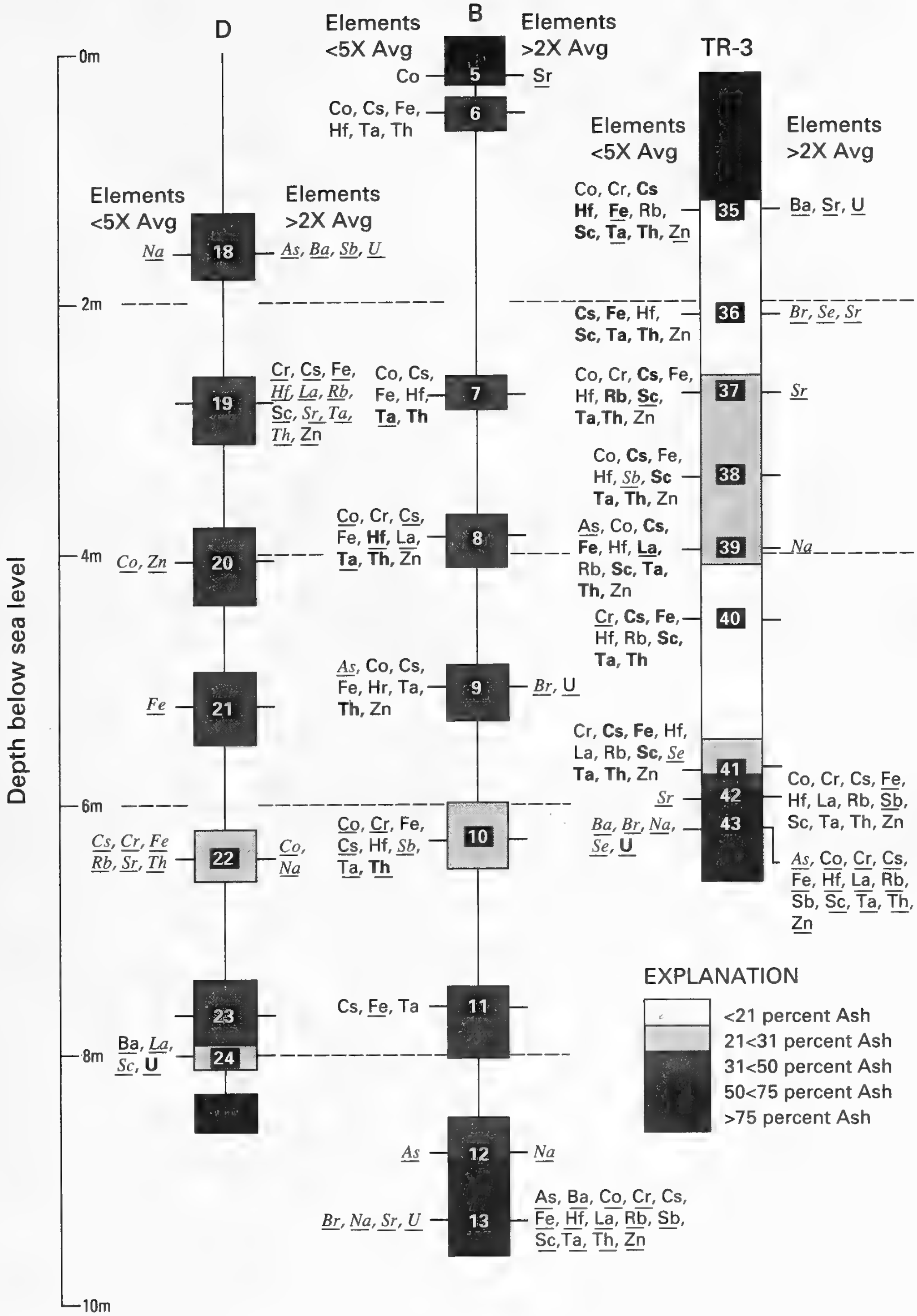


Figure 7. Ash and element distribution in cores D, B and TR3. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores D, B and TR3. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core.

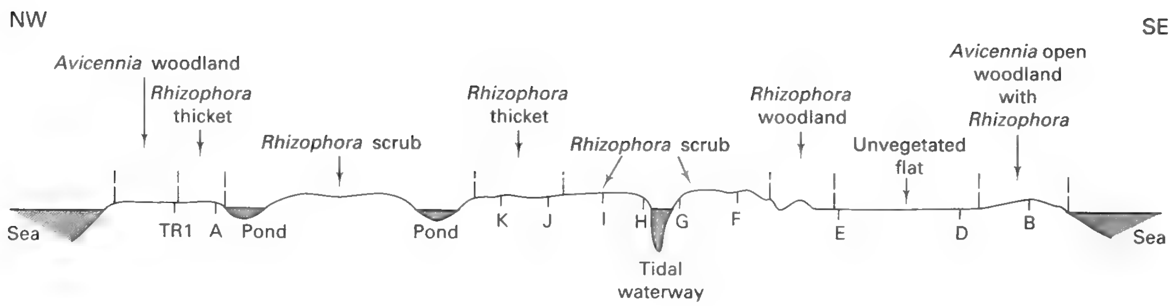


Figure 8. Vegetation types and core locations along the northwest-southeast traverse. Modification from Woodroffe (this volume)

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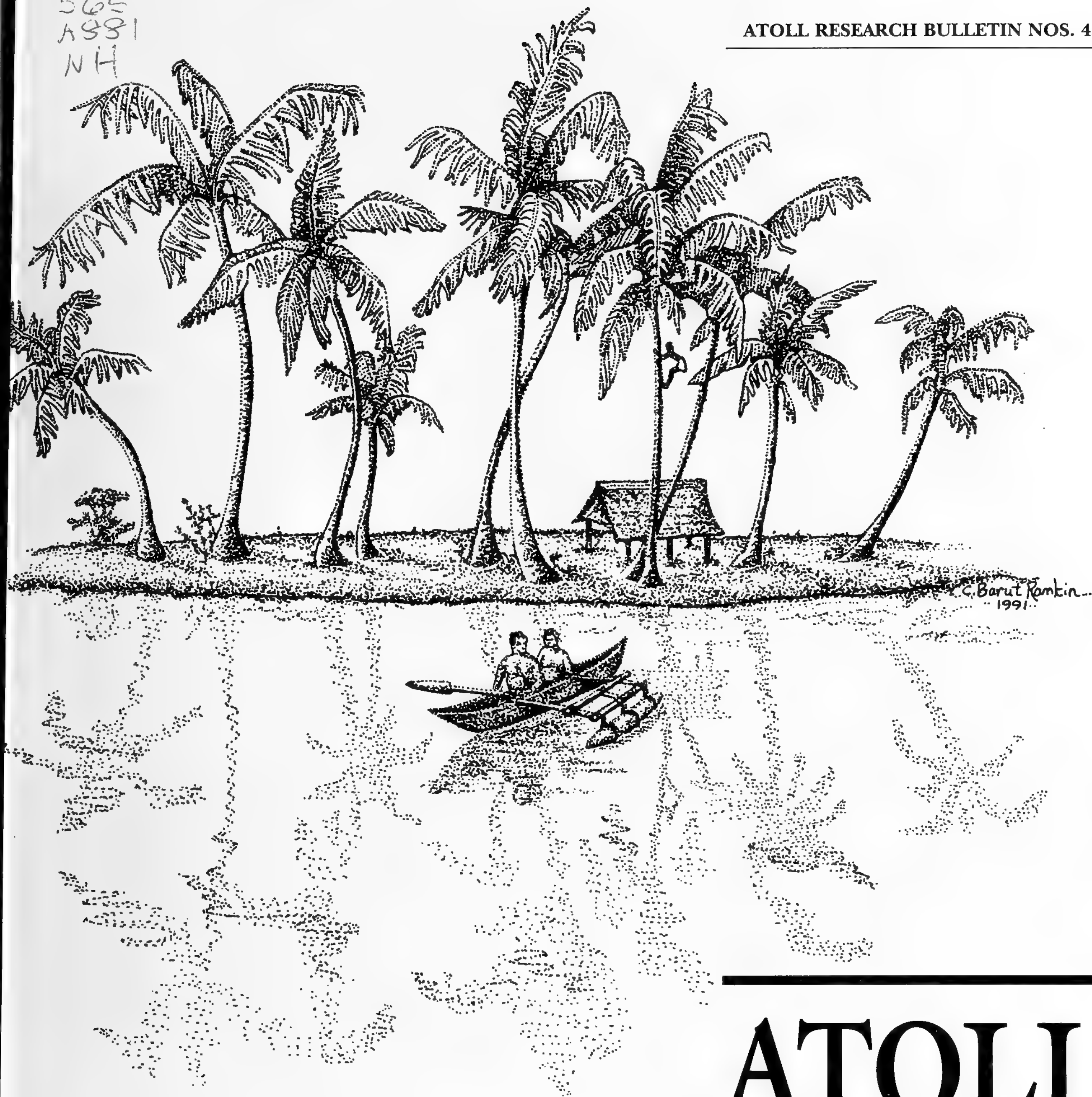

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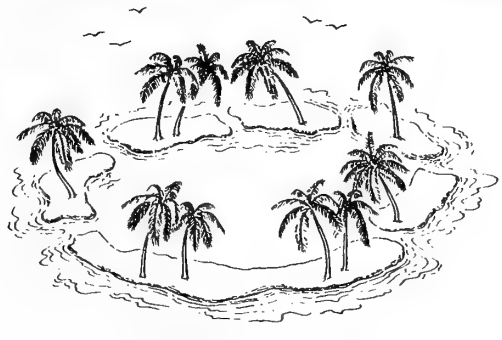

YSAN ISLAND AND OTHER NORTHWESTERN HAWAIIAN ISLANDS:
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LAYSAN ISLAND AND OTHER NORTHWESTERN HAWAIIAN ISLANDS: EARLY SCIENCE REPORTS WITH A LAYSAN ISLAND BIBLIOGRAPHY

EDITED BY

IAN G. MACINTYRE

ISSUED BY
NATIONAL MUSEUM OF NATURAL HISTORY
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WASHINGTON, D.C., U.S.A.
FEBRUARY 1996

ATOLL RESEARCH BULLETIN

NOS. 432-434

NO. 432. THREE MONTHS ON A CORAL ISLAND (LAYSAN)
BY HUGO H. SCHAUINSLAND [1899]
TRANSLATED BY MIKLOS D.F. UDVARDY

NO. 433. HISTORY AND ORNITHOLOGICAL JOURNALS OF THE *TANAGER* EXPEDITION OF 1923 TO THE NORTHWESTERN HAWAIIAN ISLANDS, JOHNSTON AND WAKE ISLANDS
BY STORRS L. OLSON

NO. 434. AN ANNOTATED BIBLIOGRAPHY OF LAYSAN ISLAND, NORTHWESTERN HAWAIIAN ISLANDS
BY ROGER B. CLAPP, MIKLOS D.F. UDVARDY AND ANGELA KAY KEPLER

ISSUED BY
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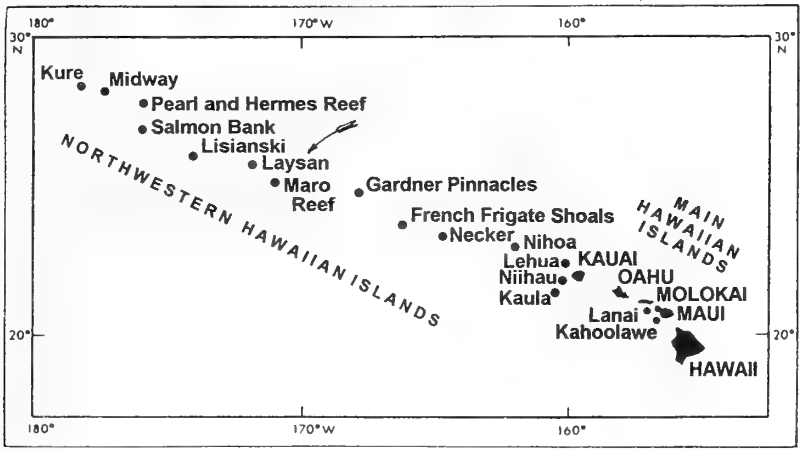
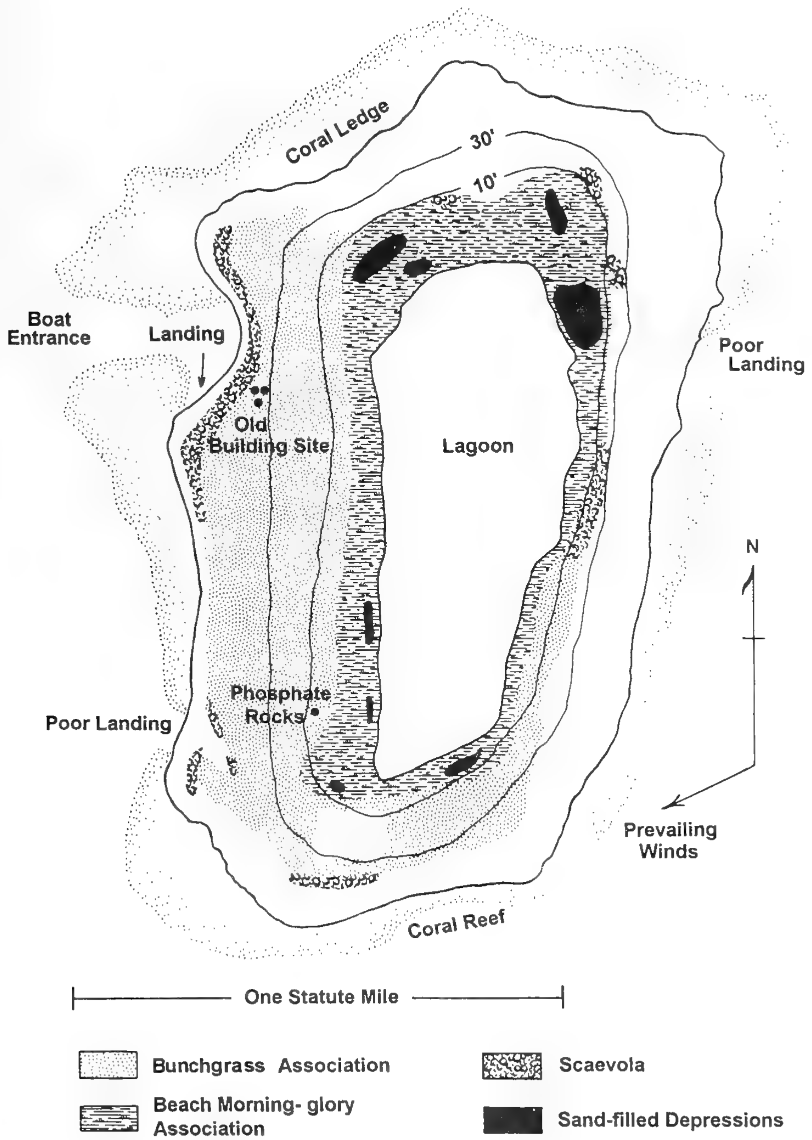
The Bulletin was founded in 1951 and the first 117 numbers were issued by the Pacific Science Board, National Academy of Sciences, with financial support from the Office of Naval Research. Its pages were devoted largely to reports resulting from the Pacific Science Board's Coral Atoll Program.

Articles submitted for publication in the Atoll Research Bulletin should be original papers in a format similar to that found in recent issues of the Bulletin. First drafts of manuscripts should be typewritten double spaced and can be sent to any of the editors. After the manuscript has been reviewed and accepted, the author will be provided with a page format with which to prepare a single-spaced camera-ready copy of the manuscript.

Laysan Island in the Hawaiian Chain





LAYSAN AND OTHER NORTHWESTERN HAWAIIAN ISLANDS:
EARLY SCIENTIFIC REPORTS WITH A LAYSAN ISLAND BIBLIOGRAPHY

FOREWORD

This Special Issue of the Atoll Research Bulletin is devoted largely to Laysan Island (Latitude 25 42' 41" N; Longitude 171 44' 06" W) the largest of the Northwestern Hawaiian Islands and one with a long history of human exploitation as well as scientific research. We are pleased to announce that this issue includes Miklos D. F Udvardy's translation of Hugo H. Schauinsland's description of his three-month visit to Laysan in 1896 and an updated annotated bibliography of scientific studies on this island. Udvardy has made it possible to present this charming early detailed account of the geology, biology, and meteorology of Laysan Island in English for the first time. In particular, he has captured the sense of excitement, enthusiasm, and apprehension experienced by this young German scientist venturing into a remote area of the Pacific with his wife acting as his field assistant. Miklos Udvardy also collaborated with Roger B. Clapp and Angela Kay Kepler in undertaking the monumental challenge of pulling together a current annotated bibliography of Laysan Island scientific publications.

We thought that it would be appropriate to include in this Special Issue the records of two unpublished journals, one written by Alexander Wetmore, an ornithologist and former Secretary of the Smithsonian, and one by D. R. Dickey, a scientist and nature photographer. These journals were written during the 1923 Tanger Expedition, which was sponsored by the U.S. Navy, U.S. Biological Survey, and the Bernice P. Bishop Museum to survey the Northwestern Hawaiian, Johnston, and Wake Islands. This successful expedition provided a wealth of information on Laysan and the surrounding islands. Storrs L. Olson has masterfully converted these hand-written field notes into print without losing their original flavor by inserting original sketch maps, drawings and photographs into the text. These journals provide valuable insight into the status of the island biota in this area during the 1920's and include reports on now extinct species.

The Hawaiian Island National Wildlife Refuge, which includes Laysan and the surrounding islands, was designated a "natural area" by the Bureau of Sport Fisheries and Wildlife in 1967. This new status limits access to these islands for scientific research.

We are grateful to the Atherton Seidell Endowment for providing funds to assist in the publication of this Special Issue. It will be an important source of information for all those carrying out research in this area or requiring comparative data for investigations in other parts of the world.

Ian G. Macintyre

ATOLL RESEARCH BULLETIN

NO. 432

THREE MONTHS ON A CORAL ISLAND (LAYSAN)

BY

HUGO H. SCHAUINSLAND
[1899]

Translated by

Miklos D.F. Udvardy

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WASHINGTON, D.C., U.S.A.
FEBRUARY 1996

Drei Monate auf einer Koralleninsel.

(Laysan.)

Nach einem Vortrag,
gehalten im Geographischen Verein zu Bremen.

Von

Prof. Dr. Schauinsland,
Direktor des städtischen Museums für Natur-, Völker- und Handelskunde
in Bremen.

BREMEN.
Verlag von Max Nössler.
1899.

Preface

On Saturday, September 2nd, 1961, shortly after the close of the 10th Pacific Science Congress in Honolulu, the Harold J. Coolidge Expedition first made landfall on Laysan Island, Hawaiian Chain, in the northern Pacific Ocean. This undertaking was the brainchild of the late Richard E. Warner, who worked tirelessly for the conservation of rare Hawaiian wildlife, and who secured the approval of the president of the Congress, Dr. Coolidge, to lend his name to the planned expedition. Warner assembled ten of us to study various aspects of the natural and geological history of the island. While in the field (Sept. 2 -10), we developed the idea that a comprehensive account of our findings should be written with all of us as co-authors. However, other duties and obligations led to the procrastination of this account. In addition, the all too early demise of three participating scientists caused the shelving of the project entirely.

One of my assignments was to translate from German to English Professor Hugo H. Schauinsland's book, Drei Monate auf einer Koralleninsel (Bremen: Max Nössler, 1899). At the time, all of us had considered it to be a rare source of scientific data about the status of Laysan's nature toward the end of the 19th century. Now, more than 30 years later, I am finally able to present this translation. Following my translation of Schauinsland's "lecture" and appended notes, I have also listed the publications which resulted from his Laysan collections. Many, but not all of these, are also found in the bibliography of Ch. A. Ely & R. B. Clapp, 1973. The natural history of Laysan Island, Northwestern Hawaiian Islands. Atoll. Res. Bull. 171.

I am greatly obliged to my friend, Professor Emeritus William E. Huntsberry (University of Hawaii, Honolulu) who agreed to meticulously check and improve my English style and grammar. Professors Dietrich Mueller-Dombois (University of Hawaii, Honolulu) and William J. Sullivan, Jr. (California State University, Sacramento) kindly checked (and improved) the translation against the original text. My son and daughter, M. Andrew Udvardy and Dr. Monica L. Udvardy also checked and improved the manuscript. Dr. Charles S. Papp prepared the map of Laysan Island. Drs. Andreas Lüderwaldt and Dieter Heintze (Übersee-Museum, Bremen) supplied the biographical data of the author. Dr. F. Ray Fosberg and Dr. Ian G. Macintyre (Smithsonian Institution, Washington, D.C.) in many ways encouraged and facilitated this publication as part of the present series.

I am very grateful to the above mentioned people, for their enthusiastic contribution to this project. Nevertheless, as a member of the 1961 expedition myself, I have decided to personally dedicate this translated work to the memory of my three, previously mentioned, fellow scientists on that expedition, the late A. Starker Leopold, William H. Usinger and Richard E. Warner.

Technical notes.

On language: wherever feasible, I rendered a literal translation of the original German

text. In some cases, however, the resulting sentence had a peculiar or misleading context in modern English, which made its comprehension awkward for the reader. Using a little artistic literary licence, these sentences have been altered, although in most cases I retained the literal translation.

On scientific names: The original names and their spellings have been retained, although in many cases both have been historically antiquated, such as the capitalization of the initial letter of some specific names. In the flora list (Appendix note No. 16) I added, in [brackets] the synonyms used by Lamoureux (1963, Atoll.Res.Bull. 97.)) and/or Ely & Clapp (1973, l.c.). The outdated units of measures and old geographic names have similarly been retained, for instance, nautical miles, Gardener Island instead of Gardner Pinnacles, etc.

On symbols: Numbers in the main text, (enclosed by brackets) from (1) to (22) refer to the author's notes in the Appendix (on his pages 85-104). These numbers have been printed in this translation of the Appendix in bold print, for example **1),** and the subsequent page numbers refer to the translated text.

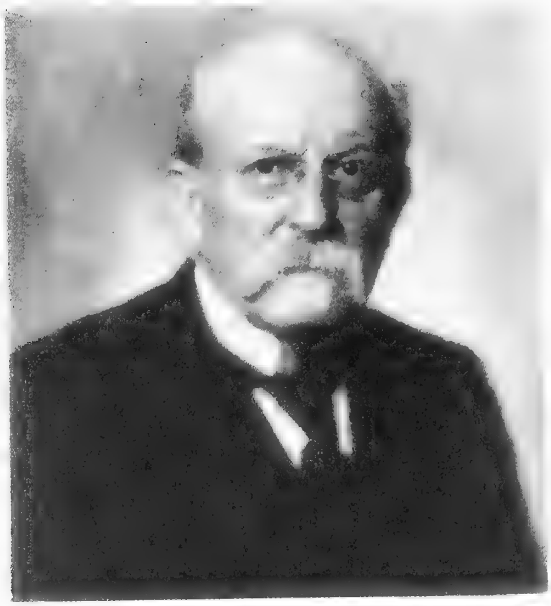
On printing: The German book printed numerous words, phrases and sentences in a spaced style. I have underlined these, though some words so marked no doubt merely served to avoid a gap in a line.

About the Author.

Hugo Hermann Schauinsland was born of a Prussian landowner family in 1857. Although his studies were interrupted by a long-lasting childhood illness, he graduated from high school in Königsberg, East Prussia, in 1878. That summer he studied natural sciences in Geneva, Switzerland, and visited the world exposition in Paris. This latter visit had a lasting impact on his interest in museum exhibits and expositions. Though not a highly merited high school graduate, he continued with university studies at Königsberg's Albertina University, under the reknowned embryologist Richard Hartwig, for whom he worked as a museum assistant. In 1883 he won the doctor's degree with a dissertation entitled "Contribution to the Knowledge of Embryonal Development of Trematoda."

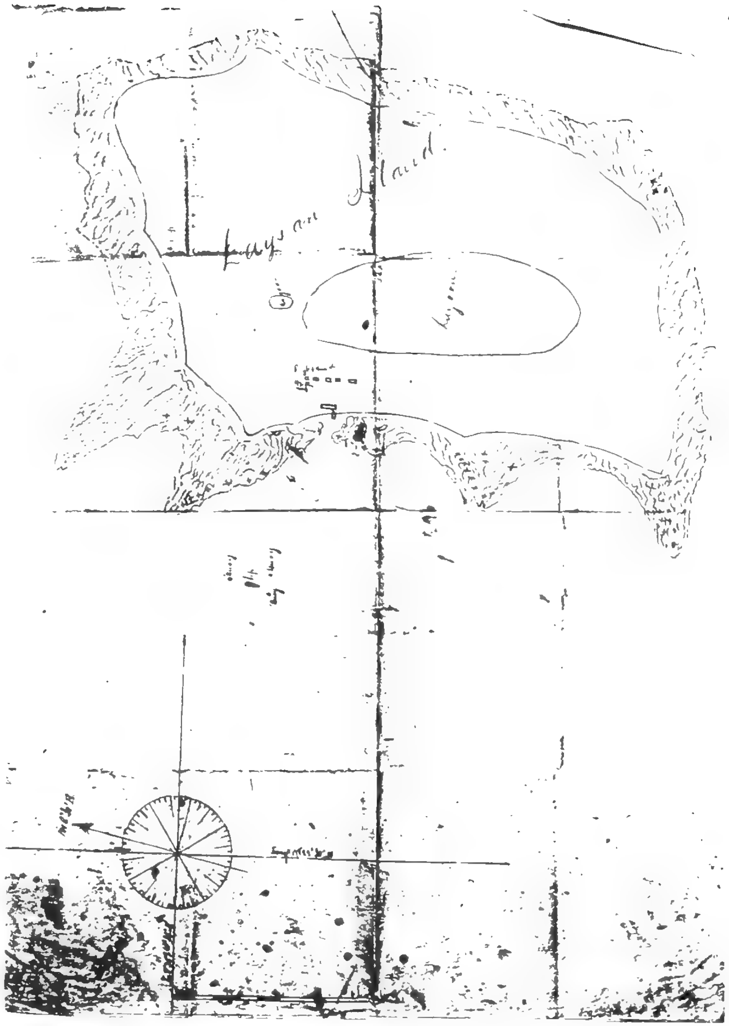
Shortly thereafter, a Prussian government fellowship enabled Schauinsland to spend several months at the famous Marine Biological Station of Naples, Italy, which had been founded nine years earlier by the wealthy German zoologist Anton Dohrn. This experience stimulated him to initiate marine biological studies of the Baltic at the Bight of Danzig (now Gdansk). However, when his mentor and supervisor, Professor Hartwig, moved to Munich in 1885, Schauinsland followed him. By then he had enough scientific work accomplished to be accepted by the Ludwig Maximilian University of Munich as Dozent (i.e., as a titular professor with the right to offer courses in his speciality). Beside teaching, he was soon commissioned to the job of curating the zoological collections of the state of Bavaria.

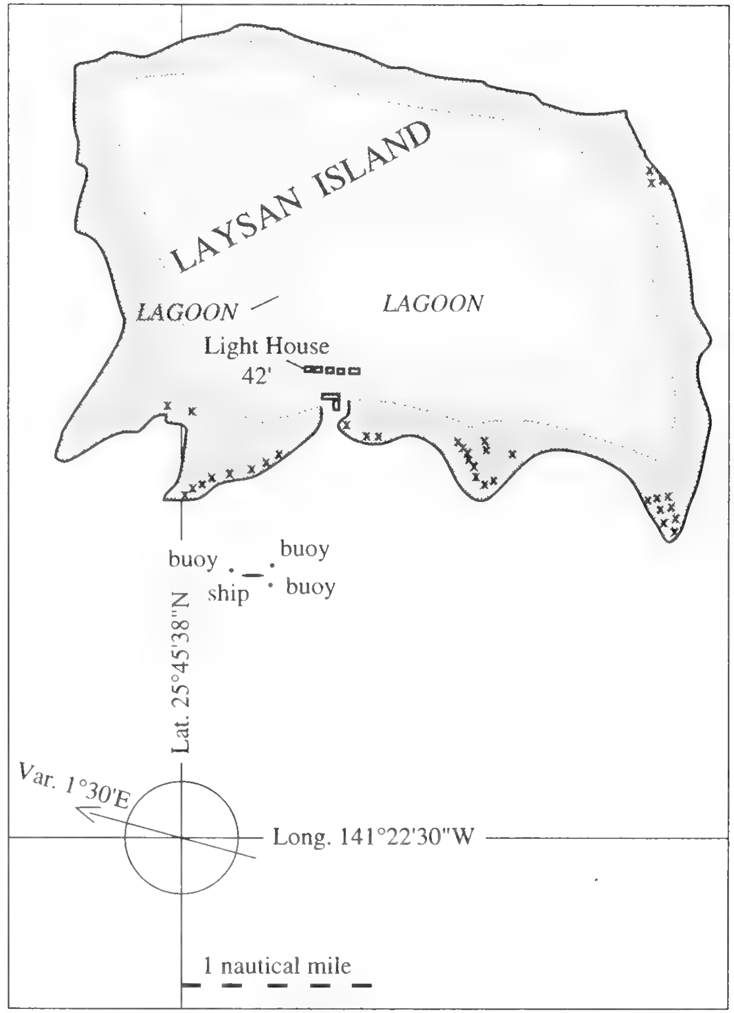
Dr. Hugo Hermann Schauinsland in 1886, as dozent at the Ludwig Maximilian University in Munich.



Dr. Schauinsland in 1927, as museum director in Bremen, 70 years old.

Both photographs courtesy of the Übersee-Museum in Bremen.





Schauinsland's sketch map of Laysan Island, which is in the possession of his granddaughter Mrs. Rosemarie Oertwig of Bremen (Courtesy of Dr. Andreas Lüderwaldt). The reef surrounding Laysan is shaded and has cross-marks that are probably collection sites.

Based on this diversified background in zoological research and museum experience, and with the enthusiastic support of his former professors and employers, he was chosen in 1887 out of 14 applicants for the directorship of the City Collections of Bremen, that bustling hanseatic city with long traditions of overseas shipping and commerce. He took over the collections on June 1, 1887, and by October of the same year had reported to the city fathers that the stores of collections were so enormous that their organization would need at least a year without attempting to procure any new material.

In 1890, Bremen opened a Northwestern German Industrial and Commerce Exhibition, and the energetic work of the new museum director greatly contributed to its success. It also helped him to establish a network of contacts with the leading industrialists and business people of Bremen who donated valuable material to the Exhibition. Moreover, these contacts led to substantial financial help, first by these private donors, and subsequently to a matching sum by the city, for the construction of a new, stately museum building for Schauinsland, the City Museum for Natural History, Ethnography and Commerce. In 1896, the new Museum edifice opened, in which Schauinsland's ideas, plans and practical suggestions had all been architecturally incorporated. Schauinsland received all due recognition: a professor's title, a year's leave, and funds for a year's collecting expedition.

Now 36 years old, Professor Schauinsland embarked, with his wife, on a journey which led him not only to the Hawaiian Islands, but, from April, 1896 to May, 1897, to the Pacific coast of the USA, to Samoa, New Zealand, Stephens Islands, Chatham Island, Australia, Ceylon and Egypt. He returned laden with rich collections. The identification of the zoological specimens alone took several years of intensive work by specialists and the resulting scientific works fill many volumes.

The subsequent 16 years (until the outbreak of World War I) saw Schauinsland as organizer of his museum; a completely new type of institution with emphasis on public exhibits to teach and educate the public about the world overseas. The novel methods of presenting the material (synthetically instead of in scientific order), including dioramas containing both natural objects and cultural artifacts and placed in a replica of their natural (or human-made) environments, were recognized by many contemporary German museologists as creations of Schauinsland's innovative mind. During 1907-1911 the museum was renovated. Also enlarged by Schauinsland's subsequent collecting expeditions (1905-06: East Asia, 1907-08: Indomalaya and East Asia, 1913-14: Oceania and East Asia, 1926: Egypt) it now fulfilled his above outlined goals of presenting the natural, but especially cultural and industrial peculiarities of overseas lands as they form coherent entities. This "Übersee—Museum" (Oversea-museum) as it is called today, is a monument of Schauinsland's activities until 1933. In that year he was forced to retire by the Nazi regime. Broken-hearted, he withdrew to his native Prussia where he suffered a heart attack. Though living in Bremen he never again set foot in his Museum: 80 years old, he died in 1937.

Beside being a highly innovative museum director and an extremely well organized collector, Schauinsland also pursued scientific studies in comparative anatomy and embryology. One of his many important contributions is the microscopic anatomy of the "living fossil" tuatara (a reptile, *Sphenodon punctatum*, then known as *Hatteria*, which he collected on Stephens Island off New Zealand) which was unknown until his publications in 1899 and 1900.

Now, almost a hundred years after Schauinsland's first, but perhaps most important collecting expedition, the pleasantly written, fascinating travelogue, "Drei Monate auf einer Koralleninsel," and the acompanying notes have not lost their importance for the scientific assessment of the natural history of the Hawaiian Islands, particularly of Laysan.

M.D.F.Udvardy

THREE MONTHS ON A CORAL ISLAND (LAYSAN)

BY

HUGO H. SCHAUINSLAND
[1899]

Translated by
Miklos D.F. Udvardy

When looking at the distribution of water and land on our globe, in addition to the continents, we may distinguish islands which reveal by their geologic structure as well as by their flora and fauna, that they are nothing more than torn-off pieces of the neighboring continents from which they were separated, a shorter or longer time ago. The best known examples of such continental islands are Great Britain and Ireland. In contrast to these continental islands, a great number of other islands show no relation to their surrounding mainlands, neither with respect to their rock composition, nor to the organisms which populate them. We may call these oceanic islands. The great majority of the mostly small and widespread islands of the Pacific Ocean belong to this category. Here also belongs the tiny and lonely coral island called Laysan, situated at 25° 46' N. Lat. and 171° 49' W. Long. While it is only some 800 miles from Honolulu, it is separated by thousands of miles of ocean from both America and Asia.

This island became the target of my research trip in the summer of 1896, not only with the intention to find out about its structure as a coral island, but also to study its very interesting flora and fauna, and to collect material for phylogenetic studies.

Since Laysan and the Hawaiian Islands have a certain relationship, to which we shall return later, we may be allowed to say a few words about this latter group of islands.

If we look at their position on a map, we notice that the islands of the group, viz. Hawaii, Maui, Molokai, Oahu, Kauai and Niihau (to name only the most important ones) all lie along a SSE — NNW line. The island chain also continues beyond Niihau in the same way; however, from then on, no habitable islands exist, rather there are only steep rocky promontories protruding from the water, or lowly sandbanks and coral islands which are either totally submerged, or are barely emerging from the water surface. These are Bird Island, Necker, French Frigate Shoal, Gardener, Maro Reef, Laysan, Lisiansky, Midway, etc. (1). Depth measurements were made a number of years ago with a planned cable in mind which was to be laid between America and Asia. These measurements showed that the latter mentioned islands rise from a high plateau that is on an average under only 1,000 fathoms of water. But they also provided evidence that, outside of this narrowly delimited high

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California State University, Sacramento, California 95819, USA

plateau, the sea bottom sinks to terrific depths north- and southward of the whole island chain. An average of 2000 to 3000 fathoms have been measured here. From this we learned that the island chain in its totality represents a monumental mountain chain that rises abruptly from the enormous depths of the sea bottom. Whereas in the NW the peaks of this mountain chain barely break the surface of the sea, toward the SE they steadily increase in height until, on the last of the islands, Hawaii, they reach heights that surpass those of Mont Blanc. Today active volcanism is restricted to this last island, though there it manifests itself in such a grandiose manner as seen nowhere else on earth. Though neighbouring Maui possesses Haleakala, the mightiest crater of the world, its fire has been extinct since human memory. Although on the remaining islands the lava fields have quite a fresh look, they surely ceased to flow an infinitely long time ago. By the way, I want to mention that all rocks on all these islands are either of volcanic nature or else they originate from coral reefs. One does not find the slightest trace of basement or sedimentary rock formations.

Consideration of the geological structure alone leads us to conclude that the youngest members of the island chain lie farthest to the SE, and that the age of the islands gradually increases toward the NW. The highest island (Hawaii) is also the youngest. The lower the other islands are, the earlier the eruptive forces on them ceased. They are geologically older and were exposed to the powers of erosion for a longer period of time. Wind and precipitation have worn down their mountain peaks and have gradually diminished their height.

Americans, especially those operating the steamboat companies that provide the connections between the mainland and the Hawaiian Islands, call these the Paradise of the Pacific. Anyone who has crossed America and has, during the several months of the journey, read upon every house, fence or rock that Sarsaparilla is the drink, or that you ought to wash yourself with Pear's Soap, becomes somewhat leary of superlative expressions, especially after having noticed the exaggeratedly enthusiastic responses of the true Yankee toward every peculiarly shaped rock formation on the prairie, and how he declares the simplest and most boring landscape as the nicest in the world (providing he has business interest in it). However, in regard to Hawaii, such suspicions are entirely unwarranted, for it really is a piece of paradise on earth, created by the delightful climate, lovely vegetation, friendliness of the people whether native Kanaka or white immigrant.

Even a short stay in Honolulu, and especially a short excursion from there, allows us to sample all these characteristics of Hawaii's nature; <u>anything that we experience there would more or less apply to the whole island chain.</u> When leaving the city we proceed through the fine Nuuanu Street towards the valley that bears the same name; here we find ourselves surrounded by the loveliest flora! There hardly exists a tropical plant that would not thrive here or that could not be grown here. The heat of the sun, although it supports all these plants, is moderated. The thermometer here shows lower values than what one would expect

from the geographic position, owing to the wide ocean with its refreshing winds, and especially due to the cool current which originates at the coasts of Japan and washes over the coasts of Hawaii. The extraordinary uniformity of the temperature also has the pleasant effect of having but a few degrees difference between summer and winter. Even though it is an exaggeration to talk about an eternal spring in Hawaii, it is certainly true that the heat there never reaches excesses that would cause drowsiness as it does in other lands at the same latitude.

Here then, at the beginning of the Nuuanu Valley, the well-to-do Honoluluans have built their dwellings in great numbers and have set up a paradise amidst palms and lovely, blooming trees. It fills a German, especially one from Bremen, with a great feeling of satisfaction to see the German names among the owners, even names from Bremen. The position of a German person in Honolulu is outright trend-setting; the most respected business firms are in German hands. I need not enumerate them by name since they are as well known here in Bremen as over there.

Now we climb higher into the valley. The air becomes cooler and more refreshing, the vegetation loses some of its lushness and naked, picturesquely rugged cliffs of volcanic rock emerge from it on both sides. After some two hours of climbing, we stand suddenly in front of a notch in the rock, on a small platform; from its height one gets an unlimited view over the land and sea. The platform opens up a view onto an abyss of awesome magnitude: the famous *Pali*. This was the place where the great conqueror, the Napoleon of the South Seas, Kamehameha the Ist, fought the last decisive battle a hundred years ago. Before his time, each island was ruled by its own chieftain; Kamehameha subjugated them one after the other. He drove the last small group of his adversaries, who had opposed him here in the Nuuanu Valley, in a decisive battle higher and higher into the mountains until they stood here against him. The killing did not stop at the gaping precipice of the Pali. The fearsome winner pressed the retreating men closer and closer to the cliff and forced them at the end to a fatal jump into the depths. A few decennia ago, the bleached skeletons of the shattered warriors could still be seen at the foot of the precipice. By now, a path has been built across the cliff wall with laborious efforts so that one can reach the east side of the island from the other side, up through the valley and over the Pali.

Stormy winds prevail here at all times, even when only a slight breeze can be felt in Honolulu. The eastern trade wind, which crosses several hundred miles of sea without hindrance, strikes here at the high mountain chain of the island. It is pressed upward and penetrates this narrow opening in the cliff wall as a gale, then glides down into the valley on the other side. There is another phenomenon associated with the rise of the trade winds on the mountain ranges of the islands. The wind becomes saturated with moisture during its course over the sea. As it is now forced to rise up from the lower to the upper, colder layers of air, it can no longer hold the same amount of moisture. This hitherto invisible moisture now gathers into clouds. Hence, the peaks of the islands' mountains are frequently shrouded

in clouds even in the nicest weather. Here at the Pali, the swelling vapors of the trade winds often present a strange and remarkable sight, when sunlight seems to fight the waves of billowing fog, and produces a strangely delightful effect. One may draw the conclusion from the above that there are enormous differences in the amount of precipitation on the islands. The east side, which is turned toward the trades, is considerably rainier and therefore also cooler than the very dry and warmer west side. Even if the trade wind reaches this side, it has already spent its humidity. Thus it may happen that we observe 320 mm of precipitation at a certain point on the windward side; while a few km away, on the other side of the mountain, only 32 mm. The refreshing trade winds blow during a greater part of the year; losing power only during some winter months when supplanted by southern and western winds, which have a fatiguing effect and most often result in a choking, sweltering heat. The island people do not like this kind of weather because several diseases prevail during its presence.

But let us return to the wider view from our vantage point. Happy green fields send their greetings from the low plains of the island at our feet; they are mostly fields of sugar cane, the main source of the island's wealth. Here and there, especially in wet spots, there are a few rice fields, keenly tended by diligent Chinese; or we can see swamps with taro fields, that aroid-like plant the root of which provides the *poi* , a favorite dish of the native Kanakas.

If we look farther away, we notice that the heaviest ocean surf does not follow the coast itself, but is farther out to sea, at the outer margin of the coral reef, which almost totally girdles the island. We see behind us the neat harbor of Honolulu, teaming with masts, among them not seldom those belonging to stately ships from Bremen. These masts are an indication of the significance of Hawaii regarding commercial traffic. This significance will never be lost but it will presumably increase, for the islands are exactly in the middle of the world highway between America, Asia and Australia.

When the air is clear, our eyes may reach the steep cliffs of Molokai, the neighbouring island. There is a narrow peninsula on its east coast which is cut off from the rest of the world by a vertical cliff wall; there the most unfortunate of all sick people, the poor lepers, languish away.

This introductory orientation might suffice to acquaint us, at least to some extent, with the peculiarities of the island chain to which we attach, as its strongly altered member, the remote island *Laysan*.

We arrived in Honolulu during the last days of May; our hopes to sail quickly on to Laysan did not materialize. The sole connection with that island is through the Guano Company, which utilizes the guano that is formed on the island, bringing it for further refining to Honolulu. The guano is a highly appreciated fertilizer; it is especially used on the cane plantations. The ships of the company, which are for the most part also in German

hands, travel two or three times each summer to the island. We not only had permission to visit the island, but we considered ourselves the company's guests during the whole time, for which we are forever very obliged. This particular time, a German ship, the well-known, fine barque *H. Hackfeld,* was scheduled to undertake the journey, but at the time of our arrival, she was not quite ready to sail. We used the waiting time for collecting trips in the surroundings of Honolulu and at times, also for visits to the ship. The first reception on board was unforgettable! The sailors' band, consisting of kettledrum, triangle and accordion, tactfully greeted us with the masterly performed, pretty song "O'Susanna," which is also very much appreciated amongst us on the banks of the Weser.

On the afternoon of 18 June everything was ready for departure; we shook the hands of our local friends for the last time and rushed on board. Our luggage, consisting of 25 large chests, had already been hauled aboard earlier. A little steamer pulled us from the harbor to the open sea where the accomodating trade winds soon filled the uphoisted sails.The sun was just setting, beautifying the lovely sight of Honolulu, surrounded by its picturesque mountains hidden under lush greenery. This view, seen every so often, causes the same delight time and time again. The sailing proceeded in an orderly fashion and next morning we sighted Kauai. The friendly captain steered us in so that we were sailing close to the island, and thus, were able to savour its beautiful coastal landscape. In passing, we noticed the German plantations, Kekaha, Koloha, etc. Kauai is the most German of the islands. For instance, Lihue, that wonderful plantation, is evidence of that which German initiative and German energy is able to accomplish. There you hear almost excusively German spoken, and the numerous Germans, viz. the worker population, living in neat cottages under bananas and mangoes, are educated here in a German school, and, edified in a German church.

We found it rather interesting that here, nearest the island, the trade winds died all of a sudden, with the sails hanging loose on their yards, though a short time earlier they blew with full force. The wind that blows across the high mountains descends only far out at sea, and thus on the coast a nearly complete calm zone exists. It may even be that an air current is created here that blows landward, contrary to the generally prevailing wind direction. Thus, I understood here how it was possible for a sailboat to drift onto the beach in broad daylight and in the best weather, especially when, an additional, unfavourable sea current was drawing it. In our case, however, a clever maneuver brought us back again into the zone of the trade wind. In the evening, we passed by the last inhabited island, Niihau, with a terrible surf at its rugged coast.

Next day carried us past Bird Island, a lonely vertically rising crater (900 ft high) with numerous bird flocks circling its peak. Of the rest of the islets, we sighted only Gardener Island, rising 170 ft above the water like a giant sugarloaf with steep, completely smooth walls. The rest of the journey passed without much variation. We had plenty of opportunity to acquaint ourselves with the ship, we even learned the meaning of "to embrace" and of sailing "by the wind" or "before the wind." We were entertained every evening by this

wonderful group of people, the sailors. The band again played the central role, comical seamen's dances were performed following its tunes. A certain young sailor made himself especially noteworthy; a young baron, sent to sea by his parents to change his lifestyle; this, according to what we learned, was indeed utterly necessary.

There was not much animal life to observe, save that of the birds. But once we saw a mighty flock of shearwaters (*Haloplana fuliginosa* G.M.) fluttering and screaming right above the water surface and time and time again picking up prey from the water. At the same time, a great school of bonitos (*Thynnus pelamys* C.V., a predatory fish related to the mackerels) appeared, and shot by the ship's bow like shiny arrows. Hastily improvised hooks were thrown over board. Pieces of cloth fixed at their ends fluttered just over the water's surface; the greedy robbers must have thought they were flying fish and jumped high and snapped after them. Soon, some dozen of them lay on the deck; they made a pleasant change in the evening meal with their tasty, though slightly dry, meat. At this time, the meetings with the schools of fish and bird flocks ended. The degutting cut in the bonitos showed that their stomachs were filled with small, sardinelike fish which fled in great schools from their pursuers. Under the water, they were pressed by the greedy predatory fish, but, when escaping, they came too close to the surface, where they were caught by the voracious birds.They were menaced from both sides. The struggle for life is hard, even in the water.

At daybreak of the sixth day, we heard for the last time the setting of sails, accompanied by the melodious tones of an English sailor's song. As we rushed onto the deck, we saw Laysan, the goal of all our yearnings.

One cannot deny that the first sight offered by the island, at least from the distance, was surprising but also disappointing. Had we not known that we happened to be in the middle of the Pacific Ocean and nearly in the tropics, we would have had to imagine that this was one of the Friesian islands before us; it lay just as low and flat above the sea, its shores were just as sandy, its green just as pale.

Soon we landed. We had already learned during the first day on the island that there was so much work to be done that we could not accomplish it in the short time allotted. Therefore, we decided to let the ship leave and to stay here until she would have her last island run in the autumn.

Laysan is small, 3 English miles long and 2 1/2 miles wide. Its highest point amounts to about 30 feet. Nevertheless, the greatest part of the island is considerably lower. One may well imagine that a high tidal wave, such as occurs from time to time as a result of earthquakes, could submerge a great part of the island. Actually, such a tidal wave occurred shortly before our arrival, resulting from an earthquake in Japan, and we had witnessed its effect in Honolulu with our own eyes. It also hit this island and rolled up high on its shores.

The soil of the interior of the island is almost entirely composed of sand. But it is not the quartz sand that we know at our islands of the North Sea. It is solely composed of limestone particles that originate from coral and mollusk shells worn down by the waves and storms. The rocks on the island are similarly composed only of limestone of various grain sizes and hardnesses. Also, they are only cemented coral sand. At times, their structure is so fine and so dense that blocks of enormous dimensions resonate sharply when hit with a hammer. Others, again were found to consist of various sized particles. They were conglomerates of larger pieces of coral and mussels.

In the interior of the island, rocks appear only occasionally, forming low and quite loose cliffs, greatly eroded by wind and weather. In contrast, they form most of the coast, where they sometimes occur in regularly deposited layers. They are highest in the southeastern part of the island where they abut the sea as vertical cliffs. They present here a really magnificent coastal landscape. The high waves, driven by the almost steadily blowing trades, disintegrate on them. But if a storm drives the water with more force against the coast, the white foam of the furious waves sprays against the rocks to towering heights and bathes them with mighty cascades! It is perhaps the most sublime sight of surf I have ever seen. The waves chew incessantly on the hard rock, undermining it and gnawing holes in it. One of these holes is connected with the rock surface through a small opening. The water, penetrating it with violent power, is pressed out through that opening with a mighty force; a force that sends it high into the air as atomized spray, like the steam from a valve of a giant steam engine; we could hear from quite a distance the hissing, whizzing sound of the escaping vapor.

The sight of the southwestern coast is not dissimilar. Here the whole surface is filled with honeycomb-like holes, among which rise sharp spines where one can hardly find a foothold. Toward the sea, the coast slopes down into a series of terraces on which shallow basins are carved out and filled with water like small, neat natural aquaria. These are only supplied with water by the upward spraying of the surf. Here, there are many kinds of snails, mollusks and sea urchins fastened to the rock and hidden by green algae. A tiny, handsome fish (*Galaxias edentulus* Bl. Schn.) also dwells here. But, it can hardly be caught by the snatching hand, even though the basin might be quite small and flat. Just when you think you have it, it skips away into another basin, sometimes higher, sometimes lower on the slope.

While the erosion phenomena are varied enough on all these slopes, they are especially interesting on the hard slopes. Here the surface is washed out into innumerable, needle-sharp protuberances and edges varying in height from a few inches to several feet. We may also find formations reminding us of a glacial kettle, especially where the surf is not very strong, at the lower bench of the reef. They have the characteristic rounded shape and are often one or two meters in diameter. Normally, they contain on their bottom a rolling stone that is put into a rotating motion by the waves that reach it, just as the glacial stream does with the kettle, by and by grinding it into a wider and more circular shape.

On the south side, peculiar, tube-like concretions protrude from the great masses of loose sand which the wind has piled up there. They look somewhat like lightning-tubes, but I can (2) not yet explain their origin. In the north, I found a deposition of real peat. According to what I know, peat has never been found at such a low latitude (3).

We have still to mention one more component of the island surface, viz. the guano, since it is the only reason why mankind visits this godforsaken island where only birds dwell. You should not imagine that this material is an evil stinking mass; on the contrary, here in Laysan it is a tidy, completely odorless mineral. Guano is found either close to the surface in a more or less sand- or powderlike form, or else several meters deep in the form of solid rock that must be broken by pick and shovel (so-called rock guano). The origin of this material is obviously different here from that found on the famous, completely rainless guano islands off the Peruvian coast. On Laysan it rains quite often and sometimes very hard, and therefore, I explain the guano formation in the following way:

The island was visited by countless flocks of breeding seabirds during extremely long periods of time. The dung, which they deposited on the pervious sand of the island, was leached out by the rain, the saturated water seeping down to the depths, where it impregnated the calcareous sands and rocks. Chemical compounds were thus formed, mostly calcium phosphate. Quite often, you can find whole geodes of neat, white crystals made from this mineral (4).

In these beds, bones and petrified and well-preserved bird's eggs occur quite frequently, indicating that the bird flocks that populated the island were already then the same as the ones now found on the island, especially the albatrosses and some of the larger shearwaters (*Puffinus*). We are also able to find in these beds, numerous stony-kerneled fruits, nuts, blobs of resin, and, above all, round pieces of pumice which, for sure, at one time passed through the stomachs of the gluttonous birds. These birds swallow everything that floats in the sea when they hungrily scout the surface. I know positively that this occurs even today. I have often been astonished at how big a piece of pumice can be accommodated by the stomach of an albatross (5).

A great part of the interior is occupied by a lagoon which is 2 or 3, rarely 5 fathoms deep on the average. It is filled with a brine of about 12—15 % salt content, somewhat varying in strength depending on the season and the rainfall (6). Its water is clear and on its shores great masses of crystallized NaCl, i.e. table salt, occur, at places clear white crystal drupes, good for the table. There are two species of algae in the lagoon, one of them has a cartilage-like consistency and forms great thick cushions (7). Next, there are enormous quantities of a small, transparent shrimp (*Artemia*), hardly 1 cm long. At individual places, their dead bodies are so piled up that there is a stench from afar. The only other living being, surprisingly, is a small dipteron, a fly, whose larvae develop in this very concentrated brine

(n.b., sea water only contains 3-4% salt). I may mention that the ground surrounding this salt lake is not entirely harmless; its slate white shores are covered by a hardened salt crust, but with a very deep, slimey mush underneath. The deceptive surface is very easily crushed under the foot of a person who carelessly stomps across it. It happened to me that while pursuing a wounded duck, I ventured too far out, sank in, and could only save myself by quickly throwing myself flat on my back. Thus I managed to work myself out from the corrosive salt broth (8).

There is a coral reef around the island. Its width is about 1/2—3/4 miles. It does not entirely encircle the island, but is broken in a few places and thus provides ships with an opportunity to get in close to the island. Anchorages that could, to a certain extent, be used by larger ships are only found at these breaks. This reef is a so-called fringing reef, beginning right at the shore of the island, but is separated from it by a channel which is navigable at high tide by small boats; however, by ebbing, it becomes shallow enough that it is possible to cross it, in many places, by wading (9).

I cannot deny that I was somewhat disappointed when first sighting a coral reef, remembering the depiction of the luxurious colors and forms described by travellers to the reefs of the Red Sea and the Indian Ocean. I was surprised when the banks emerged at low tide[1] and all the eye met was a wide plain of monotonous gray color, only interrupted by the livelier green of lush marine plants. We should not forget, at this point, that in this superficial view we only see the part of the reef that has died off, and which is also frequently covered by sand and debris. For an excursion one should choose the time of the lowest low tide. Extreme care should be exercised when proceeding closer to the outer border of the reef. Although one may arrive there with dry feet, at the next moment a somewhat higher, rushing, wave of the strong surf might cover the whole reef with deep water. Then one has to be careful that it does not grab and throw us to the ground. One might become so wounded on the many sharp edges and borders that one might not be able to swim back. Yet, it is here where the reef begins to present its beauties. There are deep hollows here[2] and in their crystal clear waters glimmer all those many delicate coral formations that we every time admire anew for their gracious beauty. Yet it is not the multiplicity of forms we admire most; we find here the splendor of colors we missed before. We have before us for the first time the living corals in their full splendor. We are accustomed to seeing their singular branches and leaflets as marblelike, sun-bleached skeletons, which now are ornamented in the most magnificent colors. Next to fine violet-blue coral stocks shine some sulphur-yellow ones, others glitter there in dainty pink, beside succulent-green tussocks. Like motley butterflies over flowers, fishes of all wonderful shapes

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[1]On Laysan the difference between low and high tide amounts merely to about 50-60 cm.
[2]Though mainly on the leeside of the island. Kraemer (Dr. A. Kraemer: Ueber den Bau der Korrallenfiffe und die Planktonverteilung an den samoanischen Küsten, Kiel und Leipzig 1897) likewise noticed (p. 66) that these "wells" belong to the leeside of the reef.

and magnificent patterns pass between the corals. The members of the coral fauna that dwell here in these "coral gardens" show many peculiar adaptations of color as well as aspects of their habits. (10). Nets are of no use in catching them. I lost several nets the first time I tried it; they got caught on the pointed and sharp coral branches. Thus, if I did not want to restrict myself to collecting only the ones that were accidentally thrown out of the water by the waves, I had to force myself to dive for them. Thereafter, I hustled about many hours of the day in these basins, rather more under than above the water, and gained a rich harvest.

Other tenants of the coral have settled more toward the outer edges of the reef, where the waves break steadily and with great force. Numerous representatives of the echinoderms, viz. urchins, of considerable size and in the most lively colors, are wedged in the solid coral rock so one can only get them loose with a chisel and hammer.

The east side of the reef is in places somewhat differently developed. The solid, layered limestone rock, which often appears on the shores of the island, continues here, covered by shallow water, for quite a distance under the surface of the sea. It joins the true coral reef only further out. In this way wide, shallow spaces are formed here, and they can easily be waded through. The bottom of these spaces often consists of a fine sand, but a sand that is different from that at other parts of the island. Besides broken bladelets and branchlets of delicate calcareous algae (especially *Halimeda opuntia*), it is made up exclusively of foraminifera shells, viz. of those tiny beings, whose shells, among others, also built most of the calcareous rocks of Rügen. The ones on Laysan are, without a doubt, he giants of their kind, since the plates of a very common, nummulite-like species attained the size of a lentil. Also, we were able to observe all these beings alive, on the stems and leaves of the kelp and algae (11) that grow here. Observing the remnants of this tiny being in such enormous quantities, found piled up in several, meter-high, dune-like heaps, it is easy to understand how important they have been, and still are in places, to the rock building processes of the earth. Coral stocks grow in the middle of this loose sand, though singly, often covered only by a few feet of water. I want to emphasize this, since not long ago the occurrence of living corals in such a habitat was denied.

Many other animals have their hiding places here. If you roll away one of the rock slabs that lie around, great ophilionids will nimbly scurry away from their retreats. One is quite often able to catch an adventurous octopus; sometimes it is so big that you have to protect yourself from its sucker-covered arms and sharp mandibles.(12). Giant, often half-meter-long, sea cucumbers (*Holothuria*) cosily stretch their cylindrical, black bodies. Hiding under the bottom sand, live numerous worms, among them an interesting *Balanoglossus*. Further out, where the real reef begins, cushions of coral polyps shine through the water in sulphur-yellow and verdigris colors. There are species whose bodies are not hardened by the deposition of lime as are their relatives, the true corals. Here and there one even finds the tiny, delicate trees on which the neat mushroom-corals grow; these later detach themselves in order to grow, henceforward, to their full size, as single animals. Tender sea roses

(*actiniae*) open up their wreath of tentacles, though they rather choose to live on rocks in the vicinity of the coast. At night, one is able to lure large, luscious langustas (13) from their retreats beneath rocky overhangs, and catch them with the help of a lantern and a harpoon (a pity that their meat tastes far from the delicacy of their cousin, the lobster). This method of catching yields good results even in the case of common eels and gay-spotted morays.

How is the more or less compact mass of dead reef and the hard coral-rock formed from the branching coral canopy? When the coral formations grow high enough that they are no longer completely covered by water during the lowest low tide, they die off. Sometimes, the tight masses of calcareous algae have already settled in earlier, and entangled the coral branches. Each wave of the sea throws debris of broken coral and mussel pieces on them, with sand filling in the remaining spaces. This sand is partly produced by the minuscle animals that live in the coral stocks and excavate their home therein, and also produced by the numerous crabs that cut the mussel shells into pieces with their claws while looking for edibles within. In addition, it is also produced, and more than likely, is chiefly produced, by the power of the pounding surf, which atomizes all of this debris. The limestone, that the organisms produced, will partly be dissolved again by the seawater, and will again be precipitated within the debris in crystalline form, binding the whole into a solid mass (14). The hard, layered limestones that one finds everywhere on the island have obviously been formed in a similar manner deeper in the sea, where the more or less fine-grained masses of fragments eventually gather. I would not deny, though, that some of these layers, consisting of fine, sandstone-like particles, could have originated through wind activity on firm land. The wind here blew the fine particles together, which, over a longer period of time, also cemented themselves into rock. Never-the-less, the main rock mass of the island originated in the sea and came to light only because of the elevation of the island.

What a fate these sand particles have, which we see rolling back and forth at the beach, playthings of the waves. They lay on the bottom of the sea and hardened into rock. They were elevated and became part of the surf zone. The surf again uses its annihilating force against them grinding them into sand again, which will again adopt a firm shape at some future date. Thus, the alternating play of formation and breakdown of this inert material could continue through immeasurable periods of time.

Let us consider, for a moment, the theory of coral islands. In the first decades of our century, the savants, among them the poet, naturalist and traveller Chamisso, were of the opinion that coral formations began growing in the depths of the ocean and built up, over time, until they finally reached the surface. Driftwood, kelp masses and other organic debris drifted together on the exposed coral and produced some humus on which seeds, carried there by currents or birds, gradually were able to form a cover of vegetation. This hypothesis, however, does not hold true because the reef-building corals need seawater of a very even temperature, minimum ca. 20° C, and also cannot grow in water deeper than 15-20 fathoms, at the most. Darwin was the first who successfully developed a theory which

satisfactorily explains all kinds of coral reefs. According to this theory, the corals settling around the island, at first form a fringing reef that girdles the island. If the island is sinking, the coral animals keep on building up the reef surface, at the same relative speed, while down below, they sink together with the island until they arrive at a depth where they can no longer survive. Since they find better growing conditions toward the open ocean than on the landward facing side, they develop better there. Thus, they gradually withdraw from the island and leave open between them a, more or less, wide and deep stretch of water. In this way, the fringing reef develops into a barrier reef. The island keeps on sinking until it is completely submerged, while the growth of coral maintains an even pace with the sinking. Now we have a ring-shaped coral reef, a so-called atoll. The atoll encirles a calm water body (in contrast to the agitated sea whose waves it holds off), the so-called lagoon, that replaces the erstwhile firm land. The majority of the thousands of coral islands which fill the enormous basin of the Pacific Ocean were developed in this way. Every ring of coral islands is a wreath over a sunken island.

Even this theory has, as of late, experienced its share of attacks and disputes. Among others, one objection was that Darwin's assumption necessitates a very powerful reef, not like the recently elevated reefs or the ones from earlier epochs. Now as far as this last objection is concerned, there are an increasing number of people who view the metamorphosed coral reefs in the mighty Dolomites of South Tyrolia, admired by so many tourists for their bold formations. The drillings, instigated by the Royal Society and attempted by Australia on Funafuti in the Ellice Islands group, were, at first, unsuccessful, but a few months ago they supplied the evidence: a penetrating drill found only solid coral rock to a depth of nearly 1000 feet (to date).

However, the original explanation for the development of the coral islands may have been more complicated than scientists have supposed, a possibility that may explain their diverging opinions. Coral reefs may presumably be formed, not only in sinking areas, but also in rising areas. There must certainly be a few places that oscillate between sinking and rising. Let us consider the Hawaiian Islands for the first point which was discussed. When artesian wells were drilled on Oahu for the irrigation of their sugar cane plantations, the bore holes found coral rock in some places several hundred feet beneath sea level. Whereas a sinking of the island could thus be demonstrated, elevation was not considered, or was thought to be very small and insignificant. My own observations convinced me of the contrary. I found on Kauai, between Tipukai and Koloa, larger deposits of solid limestone at considerable heights. Even if we believe that in this first case aeolian activity might have been active, such a theory is completely inadmissible in the second case: I have identified on the south coast of Molokai, at about 300 ft above sea level, (in other locations on this island, limestone rocks occur all the way up to a height of 670 ft) a deposit of real coral rock which consisted solely of well preserved, often very large sized coral debris and mussel shells in association with rounded pieces of basalt. It is totally impossible for the wind to have blown them up there. Their occurrence at that site can only be explained by elevation

(15).

Let us return to Laysan and try to clarify the history of its development. First I want to point out that I found several large blocks of basalt at various places on the beach, and when I worked on the coral reef, I also found them a few meters below the water surface. They were situated at places where a ship could never have gone and thus it is impossible that they could have originated from ship's ballast. Moreover, their size and shape made it similarly impossible that they were transported by driftwood. Rather, I firmly believe them to be the remnants of the volcanic rock core of the island. This might have projected above the water as high as neighbouring Gardner, Bird Island, or Kauai itself. It then acquired coral settlements which formed into a fringing reef. Aided by sinking, erosion diminished its height and finally it disappeared under the surface of the sea. Thus, the coral reef developed to a regular atoll with a central lagoon. This period of sinking was followed by one of rising. The lagoon diminished in size, masses of sand and debris diminished its depth and, finally, it's connection with the open sea became barred. Still, this did not happen all of a sudden. From time to time, perhaps at times of great storms or tidal waves, the ocean waves still penetrated it. In its relatively shallow basin the water quickly evaporated again; thereby becoming more and more salty. In the end, it became the salt lake, which we now find on the island as the last remnant of the atoll's lagoon. Then, the atoll was again girdled by a fringing reef of younger coral formations. The huge coral blocks that lay high on the western beach on top of the cliffs could not possibly have been rolled up there by the power of the waves. They are evidence that, apart from the great elevations and subsidences mentioned earlier, minor ones must also have occurred. Other evidence is provided by the coral limestone rocks in the interior of the island, still standing 20 feet high in spite of their great corrodability. On the other hand, in the guano pits, at depths way below sea level, numerous bones and bird egg-shell remains are found, often mixed with single, larger pieces of coral. I have even observed, at one site on the east side of the island, that the guano strata continued for a considerable distance under water as part of the sea bottom!

When we attempt to clarify the history of the whole Hawaiian island chain, to which Laysan certainly belongs, we get many clues from the study of their biota. Such a study may as well serve as an example of how the summarizing of small observations enables us to gain far-reaching conclusions, I will delve a little longer into this subject. The Hawaiian fauna is very peculiar; hardly any other island group has so many specific characteristics. There are no native mammals whatsoever. However, on the contrary, there are very many characteristic birds, most of which are entirely endemic (i.e., not only the species but also their genera occur solely on the Hawaiian islands). Only a few of them show relations with those forms that populate the remaining Pacific islands and Australia. Even fewer have very weak affinities to America, indicating that only very rare and certainly very old relations existed between this continent and our island group. The great specialization of the avifauna, which does not exist anywhere else to such a high degree, testifies either to the very great age of these islands, or the proximity of a very old, now defunct landmass from which the fauna originated.

There are very few insects; among them the beetles are especially characterized by peculiar forms which belong to the perhaps most primitive known beetle groups.[3] Almost all of them are extraordinarily tiny. The only ones to reach the islands were those able to survive a very long transport, e.g. in cracks of driftwood. The lack of very many important and cosmopolitan groups indicate how unfavourable the conditions were for immigration. The extreme specialization of these insects again teaches us that the colonization by the same species has not been repeated; thus the original, primitive forms were retained and were not changed by many crossbreedings.

The number of land snails is very large and characteristic throughout the Hawaiian Islands. Quite often they show relationships to forms which occur otherwise in different parts of the world, but not in the Pacific area. This can only be explained by the fact that they became native to the islands during a very, very ancient period, viz. when the distribution of the global land molluscan fauna was entirely different from that of today. The local distribution is also very peculiar! For example, in the family Achatinellidae, there are not only species but even genera that are restricted to one of the islands. In additon, the more we proceed from East to West the more specialized they become. Thus, Oahu and Kauai have the most deviating forms. There are also, among the other land snails, genera that belong solely to Kauai; this fact again indicates that the western islands are older than the others.

The highly peculiar and rich flora also shows greater specialization in the West than in the East. Kauai has the most, Hawaii the least specialized forms. 3/4ths of all species are endemic. Indications of relationships are found with America and with the colder areas lying toward the Northwest.

Again, summarizing the above, we can conclude that the volcanic activity ceased first in the west, i.e. that Hawaii is the youngest island, and that the age of the islands decreases from east to west. The long-lasting erosion, together with sinking, has already accomplished its work in the west. Accordingly, we may be allowed to consider the aforementioned shallows, northwest of Kauai, as the oldest, now sunken land, from which the erstwhile populating process of the islands has taken place. Even Laysan is a remnant of this land. Laysan, together with the rest of the other reefs and rocks which are in that relatively shallow area, shows us the bridge through which Asiatic forms could have migrated; the other shallows which lead toward the other Pacific islands show the way taken by those organisms which even today display relations with Oceania. Two shallower areas between San Francisco and Hawaii are perhaps suitable for explaining the connections that have existed in the distant past between these land areas.

[3]Compare with A.R. Wallace, Island Life. 2. Edit. London 1895.

Considering the majority of the Pacific islands, we find indications of eternally long isolation. Taking in account also, that all islands, almost without exception, consist of volcanic rock or are coral islands, probably also on volcanic foundation, and also considering the findings made when studying the flora and fauna, one might conclude, with a certain degree of probability, that at this location on the earth, the division of water and land, of continents and islands, remained to a large extent the same (not so that where there are now islands there was a continent earlier, and vice versa).

Let us again turn to Laysan after this diversion. Its vegetation shows similarities with the flora of the Friesian Islands, not only when viewed from a distance but also when studied up close. We find, here as there, plants of low stature, a lack of trees, the dominance of grasses and the dominance of a gray-green color. Among the 27 species that comprise the flora of Laysan (16), we find, at first, a number of cosmopolites with characteristics so favourable for dispersal that they settled almost everywhere on the tropical coasts. The rest belongs to the Hawaiian flora. It is worth mentioning that some of them occur in Hawaii only at considerable elevations on the lava fields, whereas they grow here only a few feet above sea level; perhaps again another hint revealing that Laysan was not always as low in altitude as it is today.

Foremost among the characteristic plants, is a grass with long reedlike leaves (*Eragrostis Hawaiiensis* Hdb.). It grows man-high on the lower, and therefore wetter, sites on the island, while in dryer places it grows to only one meter. It does not grow in coherent mats but singly, in bunches, with a rootstock 1/4—1/2 m in diameter. Since the bunches are well spaced with some room in between them, and since this bunchgrass vegetation covers most of the island, it attains a very special appearance. Next to this grass, the commonest plant on the island is a goosefoot (*Chenopodium sandwicheum* Moq.). Its leaves and flowers show great similarity to our garden goosefoot. It is a strongly branching shrub of 3/4 to 2 m height, in older specimens with almost arm-thick stems. It forms an almost impenetrable thicket because the single bushes begin branching from the root and the branches of the tight growing individuals interlock. This is not only the most favoured retreat of the small land birds of the island, but also for a few of the large sea-birds such as the boobies and frigate birds which use it exclusively for the foundations of their nests; they bend the top branches of the bushes and interlace them with broken-off twigs.

The nicest plant on Laysan is, without comparison, a man-sized shrub, *Capparis sandwichiana* D.C., with dark green leaves, and neatly built large, white frail flowers, each with a bunch of long swaying stamina hanging graciously from its cup. The splendor of the flower lasts only one night; it opens first at sundown and its life comes to an end the next morning when the sun has hardly raised itself above the horizon. It is not only for its form that it is listed among the most beautiful plants I know, but its charm is also increased by its intoxicating, highly pleasant fragrance. If the night breeze wanders over the blooming shrub, the air becomes filled with its perfume. By the way, all plants of Laysan, even totally

unpretentious ones, have a pleasant smell. This is understandable since the island has very few insects and we can assume that the color and odor of the flowers exist as extreme lures for the insects that the plant needs for fertilizing its flowers.

Further, we should also mention among the pecularities of the flora that the plant individuals display great lushness, greater than those on the fertile lava soil of the Hawaiian islands. Many share a trait with their Hawaiian relatives, in that their appearance is tree- or bush-shaped, whereas elsewhere they only grow as herbs, e.g. the aforementioned goosefoot and the common portulaca (*Portulaca oleracea*). I also observed that all solitary-growing low plants have rosette-like growth-form, while the taller ones make a dome-like structure with their arched branches.

Although the contrast of the seasons is only slight, some plants will be influenced by it. Many lose their leaves, others dry up (especially the above-mentioned bunchgrass and the goosefoot), dressing themselves with fresh greenery only during the rainy winter or in spring.

Not too long ago, palms have also lived on the island, and, as the many remnants of their rotten stumps show, they were very numerous. However, the last living examples died off a few years ago, and, since we cannot find a spot anywhere on the island to escape the burning rays of the sun, we miss their shade-providing crowns. It is not unlikely that castaways contributed to their demise, for at times, they were for sure present on the island. I found heaps of coal, in a few places, still showing the characteristic structure of palm wood. These could have been remnants of campfires, or else signs of fires kindled by carelessness. A final noteworthy observation about the flora of Laysan is the complete lack of ferns, mosses and lichens.

The waves often drive plant material from faraway lands to the beach. Besides various nuts, beans and other hard-shelled seeds, even big tree-trunks are stranded across the reef. These rarely originate in Hawaii., but mostly belong to conifers from the coasts of Northwest America or Japan. Their origin could only be ascertained by closer scrutiny.

By far the most interesting part of the <u>land fauna</u> of the island are the birds, (17) of which first the five endemic species of Laysan should be treated. Is it not a wonder, that here, on this tiny island in the middle of the endless ocean, we find in fact, five different <u>land birds</u> which do not live anywhere else on earth? They are a duck, a rail, and three small songbirds. Though all show relations to Hawaiian forms, they are definitely different species. <u>They are obviously remnants of the fauna of that previously mentioned old, presently mostly sunken land, remnants that survived on this island</u>. They must have been isolated from the other Hawaiian islands for a very long period of time, at least long enough for different, new species to have evolved from the original stock (since we could not think that they also

occurred on Hawaii in the past and died out there at present).

We could even conclude from their behavior on the island that, they are the last remnants of an erstwhile numerous bird fauna. I could almost say that they display a depressed nature, they are not rulers any more in the area they inhabit. We can never see them rise, rejoicing, into the sky, they fly low over the ground, and hop from bush to bush. They must struggle hard for their existence, since they were forced to adapt to a habitat, and to habits, that were originally totally foreign to them. The only survivors were those which were able to adapt to all the changes of their original habitation; the others perished.

Some of these adaptive features are very interesting. The dominant birds of the island are the sea-birds, and the other birds must subordinate themselves to them, though they may, at times, support themselves through the sea-birds. The finchlike bird *Telespiza cantans*, earlier evidently a seedeater, transformed almost entirely into a carnivore. Among other things, it found that the eggs of the almost year-around breeding sea-birds are as nutritious as they are tasteful. It opens them with a few strokes of its strong, sharp bill and carefully sucks out their contents. It carries on with this so boldly, that the breeding parents are very reluctant to leave their eggs for even an instant. During the exchange of partners while breeding, for example, the male comes back satiated from the sea to relieve his mate, so that she, too, can feed herself. The male positions himself tightly at the side of the incubating female and shoves her off the nest so that the egg becomes unprotected for only a second. And yet, the small *Telespiza* is often able of carry out its thievery during this brief moment. The tiny (just a few inches tall), quaint rail (*Porzanula Palmeri* Froh.) has also become accustomed to an entirely new life history. It has become completely flightless; it hardly uses its short wing-stumps to aid it while running, as it scurries around like a shadow, with mouse-like speed, across the sand. Originally a marsh bird relying on worms for food, it has become almost omnivorous here, and it is again, the sea-birds in particular, that contribute to its support. Although it cannot open their hard-shelled eggs with its own thin bill, I have often observed it participating in this tasty meal, after a finch had initially broken open the egg. Nor does its diet pass up the island's abundant dead birds either, but instead, tears nourishing shreds from their decaying flesh, in addition to deftly devouring the flies and numerous beetles that buzz around the rotting carcasses.

Of the others, I only want to mention the neat little red bird, *Himatione Frethii* Roth. Its nearest relative, *H. sanguinea* Gmel., is still one of the commonest birds in the higher elevations of the Hawaiian islands, where it gladdens the eye as it flitters around in the *Metrosideros* trees and collects honey (and perhaps also insects) from their garnet-red flowers, whose brilliant color its plumage wonderfully resembles. This principal food plant is missing on Laysan, but the honeysucker still hops busily here, from shrub to shrub, searching for food in the local flowercups, especially favouring the larger flowers of the aforementioned *Capparis* shrub. This bird provides a good example how a new species may arise through isolation. Despite its great resemblance to the Hawaiian form, it differs

sufficently from it by having a somewhat different nuance of colors in its overall red plumage (having some brownish feathers underneath the tail which in the Hawaiian relative are white) and, by its somewhat shorter beak. Furthermore, it is definitely the hummingbird-like bird which Kittlitz mentions in l834, following a report of the ship's surgeon Isenbeck, who made a brief visit to the island in l828. It does have, in fact, a certain resemblance to a hummingbird as it buzzes from flower to flower.

Anyone stepping onto the island for the first time, is immediately surprised by the apparant fearlessness or tameness exhibited by most Laysan birds. Our meals were always accompanied by the presence of the dapper yellow finches (*Telespiza*). Whenever we sat at the table, a few of these pert little fellows would immediately appear, flying in and pecking at the bread that was directly in front of us. They were bold enough to sit on the rim of our plates, sharing our rice and bacon. We had to shoo them away with our hands, as if they were flies, so that our meals would remain undiminished. After dinner, if we sat outside in the shade of our cabin to be refreshed by the tradewinds after a hard day's strenuous work, it would not be long before one of the pretty little brown birds (*Acrocephalus familiaris* Rothsch.) would appear. It would alight on an available knee or perch on the back of a chair to boldly stare at us, or sometimes just to sing us its lovely song. Once, one of these brave little songsters decided to sing its favorite tune perched upon the upper edge of the open book that I held in my hands. The finches were the best songsters on the island. Even when we caught them, they often played their vocal flutes while we held them in our hands, although I must convey some uncertainty as to whether these were indeed vocalizations of confidence, rather than expressions of a certain immediate distress. The quaint rails were our steady companions when working. We could hardly open the door of our laboratory without a few of these small fellows coming in with us, rummaging eagerly through our collections to enjoy the innumerable flies which buzzed around them. It was utterly comical to observe them as they would interrupt their hunting for a moment, in order to warble their most remarkable song, which had a certain similarity to the clanging of the loudest sounding alarm clock. When we were skinning birds, they would even hop bravely right up onto our preparation table, to pick a piece of suet or meat directly from our fingertips.

The seabirds displayed the same confidence. When we chose to walk directly through an albatross colony, some birds would give us room without shyness, but many would hold their ground so tenaciously, that we were forced to give them room in order to avoid trampling them. We often stood so close to them that they pecked, highly indignantly, at our feet, which caused us great pain, considering the size of their powerful beaks. This was the behavior of at least the young albatrosses. The adults only took to flight when they decided that we really had some evil plan in store for them. Therefore, we were able to collect all but a few (duck, *Himatione*, and those species that are only transient visitors on the island) of the Laysan birds without resorting to the help of the gun. There were times when the birds' confident tolerance of us would rapidly change into insolence. Once, a frigate bird making a quick sweep through the air, stole the cap from the head of a Japanese worker, carrying it

high into the sky, where it played for quite some time before dropping it. The bird repeated this scenario for several days thereafter.

All evidence indicates that the birds of Laysan have not learned to fear man and his activities, and that the few years during which the island was visited were not sufficient to teach them these experiences. One day, after a short signalling mast had been raised, an albatross, returning from the sea and certainly never having seen such a thing before, flew into it with such a force that the impact sheared off one of its wings, just as if it had been cut with a knife. On another occasion, a Japanese, rushing home from egg collecting with two full baskets in his hands and daydreaming about his forthcoming feast, was struck from out of the blue in the neck with such force, by a low flying albatross, that he fell forward into the basket of eggs. The activities of most of the birds that visit the island briefly, only to stay in passing, are exceptions to this behavior. Among these, the curlew (*Numenius tahitensis* Gm.) appears to be relatively bold, thereby revealing, that its home territory lies in an area that is relatively free of people; while the plover species, especially the golden plover (*Charadrius fulvus* Gm.) is extremely shy. Laysan's vegetation, lacking any appreciable cover, made very difficult to sneak upon them. To collect them, I often had to crawl on my belly over the ground for several hundred feet while approaching them, and sometimes, I could fool them by swimming toward them across the water, while they were foraging on the beach. They had obviously learned enough about man's treachery on their home grounds.

Laysan is a true bird paradise; nowhere on earth is there another place like this. The land birds occupy an inferior position, enduring their role of barely being tolerated by the seabirds who are the dominant and ruling class here. Next to the seabirds, all others take second place, and their character has a marked influence on the island. Seabirds rush here from the vast expanse of the North Pacific, to carry out their breeding duties. The island is ideally suitable for this, with its sandy soil. Many other uninhabited islands have a rocky substrate which makes them unsuitable to the shearwaters and diving birds who often require meter-deep burrows to make their nests in. Huge masses of birds come to breed here! During our arrival here when we first approached the island, we could see from quite a distance away, a veritable cloud of birds looming over the island. The flocks of storm petrels (*Haliplana fuliginosa* Peale) that were milling around in the distance, looked like a swarm of bees. It is difficult to estimate the numbers in such a multitude. The numbers making up those bird clouds, however, were probably in the several tens of thousands, perhaps even hundreds of thousands. There are some locations on Laysan where literally every square foot of land is occupied by breeding birds. It is virtually impossible, even for a cautious person and especially at night, to take a step without his foot endangering the birds. Moreover, the breeding birds are not only distributed horizontally on the island but also vertically, since they live not only next to one another but also over and beneath one another. There are wide expanses that are literally undermined by the burrows of the different species of shearwaters, especially where the sand is rather loose and the vegetation sparse. Nothing is more difficult than crossing such a place! The thin sandy covering over the burrows breaks through all the

time, leaving you with every step to sink knee-deep with one foot, and then with the other. Where the shrublike goosefoot forms thickets, there are not two, but four parties living above one another. The booby and the frigatebird make their nests on top of the shrubbery. Some of the landbirds prefer to nest deeper below in the branches (mostly *Acrocephalus*, but at times *Himatione*). Below them, shaded by the branches at ground level, is where the gorgeous tropicbirds breed over the burrows where the black shearwaters raise their young in underground apartments. And so, with the birds living in four vertically stacked levels (stories), the comparison of these bird cities to tenement houses is easy to see. Just as a lack of enough living area forces people to build vertically and live over one another, the crowds of birds overpopulating Laysan are similarly forced into selecting any available vertical space as suitable living quarters.

Despite this excellent utilization of existing and available space, there is not enough area on the island for all the bird species that breed on Laysan, to gather there <u>at the same time</u>. They must alternate with one another, as one species ends its breeding cycle, the physical location made available by its departure, becomes the new breeding site for another; while one species is leaving the island, another is arriving. A constant busyness of simultaneously arriving and departing breeding traffic prevails with the result that one can find breeding birds during almost all the seasons on Laysan. This phenomenon deserves special attention, even though it occurs in the tropics, where the timing of the breeding period is generally much more irregular than at our latitudes. This breeding habit, an adaptation which presumably has been developing over many thousands of years, has resulted in the existence of a very strict sequence and timing schedule governing the arrival and departure for every single species.

For several years, it has been observed that the petrel (*Oestrelata hypoleuca* Salv.), which has undermined most of the island with its burrows, arrives between the 15th and the 28th of August, without any deviation outside these dates. The evening of the 17th of August 1896 is clearly fixed in my mind. The sounds of the island birds were less noisy than usual due to the absence of both the raucous terns, who had already raised their young, and the hungry, begging cries of the thousands of juvenile albatrosses, who had said their goodbyes to this place where their cradles once stood, in their rush toward the immense ocean that would, henceforth, become their home. We traced our steps back from the promontory, where we had been trying to spot the sail of the boat that would be taking us from the island back to a more civilized port. The golden reflections of the setting sun were fading and the fine crescent of the rising moon began to glow like silver. At that very moment, my eye, which by now was trained and familiar with every movement of our sky-plowing friends, spotted a new apparition. Against the background of the fading evening sky, the sharply contrasted silhouette of a beautiful flier appeared, demonstrating its unique aerodynamic ability in flight, by slicing gracefully through the air at amazing speed without wingbeats, performing these daring maneuvers with a remarkable elegance. As it was making this abrupt and unfamiliar appearance, we knew that it must have been a new species and that we were

experiencing the arrival of this new species on the island. The next evening there were more arrivals and on the third evening, they filled the island sky by the thousands. They were petite birds, barely attaining pigeon-size, and, from that moment on, they dominated the island so thoroughly that the few remaining breeding pairs of tropicbirds, terns, etc. retreated from them, appearing distressed by the arrival of so many noisy neighbors. On land, they were nocturnal, living underground in deep burrows. By the light of the moon, we were able to observe them busily using their delicate feet to remove the loose sand which had accumulated during the year inside the unused tunnels. There were loving couples who bravely stood by their chosen piece of ground, defending a future household against intruders. They could not accomplish this without the occurrence of a quarrel or a fight, and the various vocalizations that they required. Barely two days after their arrival, the whole island resounded with these, not exactly beautiful "songs". They sang their songs under every bush, from the space between the boxes which were piled up in front of our dwelling, and unfortunately, even from under our sleeping quarters. The song's musical appreciation value falls somewhere between the sounds "that directly irritate most people into anger" and the sounds that are like the incessant utterings made by newborn babies and only appreciated by their parents. As if by some stroke of magic, the whole appearance of the island was transformed.

What an admirable drive the bird has, a drive which directs it as it flutters over a thousand miles of ocean, with an overwhelming, heartfelt compulsion to rush back to the place where its cradle once stood, in order to fulfill its parental role and duties. One is awestruck by the bird's ability to accurately schedule its arrival time, almost to within an hour; where is the compass that guides its flight through the storms and hurricanes over the vast ocean toward this tiny speck of land?

A few months later, the appearance of the island was again changed by the immigration of an even more impressive bird than the one just described. In the last days of October, the first outposts of the magnificent albatrosses appear, and a few days later, from a higher vantage point, the island looks as if it were covered by large snowflakes. There is hardly a spot from which the dazzling white plumage of an albatross does not reflect back. There are often so many of them that many must be satisfied with inferior sites, and even more are forced to move again.

Of the invasions of the other seabirds, I shall only mention the terns, because of the shear magnitude of their invasion. During the first few days, when most of the birds are still busy searching for a suitable nest-site, the fluttering multitude of these birds cause the island to look, from a distance, as if a heavy smoke curtain lay above it.

As one can see, the struggle for life on Laysan is, by no means, easy. This is verified by further phenomena. For instance, it is curious that all of the breeding seabirds on Laysan lay only one egg, while their relatives at other latitudes have a larger clutch. One species of

booby (*Sula cyanops*), lays two eggs, but generally raises only one of the chicks. The only explanation I can offer for this one-child rearing system is that their foraging task is so difficult, that only one child can be reared, without taking too great a risk.

For a naturalist, a stay on the island is of the greatest interest because it offers a rare opportunity, seldom surpassed anywhere else on earth, to closely study its wildlife, and especially, the most intimate behaviours of its birds. In our homeland, which has been dominated for thousands of years by human culture, we are no longer able to observe animals in their natural state, because their original behaviours have become dominated by a justified shyness toward our presence; and therefore, we can only obtain the most superficial impressions of them. In contrast, the animals on Laysan behave as they really are, without any fear. They had not yet learned to consider us their enemy, and therefore, we were constantly in a position (thus unbiased) to study not only their objective behaviour, but also and more specifically, their emotional life and their spiritual character. We were amazed to discover how much direct comparison to human characteristics, we were able to observe in a creature which is generally considered, by the majority, to be a "lower" form of life. This made it simple to differentiate the birds according to their temperaments. For example, it was easy for us to identify the tropicbird as a choleric type, by observing its constant quarreling, the strict rearing of its young, and its bad tempered response to almost every little thing. This temperament was already displayed by even the smallest of their downy chicks. On the contrary, the chicks of the stoic albatross exhibit a quiet, agreeable, but somewhat feeble-minded disposition; quite opposite from the pedantic, eternally fidgeting, sanguinistic tern, which spends every day and night feverishly maintaining itself or its family. Despite its successful achievements, the tern's bold confidence lacks a reasonable sense of caution, which often leads it into many failures. The black shearwater (*Puffinus nativitatis*) however, has a decidedly melancholy disposition. It spends the day quite calmly, sitting still in its underground home. However, at night, its voice when heard for the first time, instills a horror in the listener, with a sound that I can only compare to the sighing moans and cries of lament made by a very unfortunate person who is totally depressed about his life and about the world. I can still vividly recall the strange impressions of those spooky, soul-shattering wails welling up from the ground all around us, as we rested from the heat and work of our first day, in the dark night outside of our dwelling. Indeed, only a person with a truely tortured soul could moan and groan in this manner. We now understood why the Portuguese call this bird "the souls of the damned."

Observing the love and family life of Laysan's birds is an uncommonly appealing activity. The one reason which begins and guides their journey to the island, the unconscious drive for the survival of their species, is the same reason that rules them during their entire stay there. When their goal of successfully producing the next generation, is fulfilled, most of them leave the island.

All of the seabirds on Laysan live in strict monogamy, and, as far as I could observe, their

marital relations are truly exemplary. Mated pairs cling together in tender love. This is exemplified by the shearwaters, who are not only constantly side by side, but also face one another, gazing loving, for hours at a time, into one another's eyes. From time to time, they will tenderly caress one another's neck feathers, whereupon the fondled one will respond by contentedly lowering its head, visibly communicating its appreciation. They are quite often seen billing, just as pigeons do, which is comparable to our kissing. It is a sign of tenderness that, in this act, they do not wound or hurt each other with their needle-pointed, hooked bills. And yet, I have often experienced the very opposite: a single bite was quite enough to result in a heavily bleeding wound on my hands.

Another quite charming love display is the <u>mating flight</u>, as I wish to call it, of the black tern (*Haliplana fuliginosa* Gm.), which I found carried out so beautifully in no other birds. On quiet afternoons, when the sun has already set, a couple will separate from the rest of the flock and, following one another, rush toward the sea, now with slow measured wingbeats, and then shooting forward, or floating away almost motionless. Then again, they perform the most daring turns, while simultaneously rising high into the air only to sink down again immediately thereafter. Male and female fly tightly above on another, and together, they carry out each maneuver in such tight precision and with such uniform wingbeats, that it seems as if their two bodies were given life by one spirit, and directed by one will. The gracefulness of this flight display is utterly enchanting, and is noteworthy in revealing the emotional life of birds. It is obviously triggered solely by passionate love and totally mutual devotion. Would we not find this enraptured, coordinated veering through the air, this delightfully rocking, and stormy, wild flight, comparable to the fiery dance of a lovestruck human couple? And how much more affectionate, how much more graceful it seems when performed by the children of the air!

The drive which governs the bird to partake in these parental pleasures must be <u>irresistable</u>. Albatrosses whose eggs have been stolen, will still sit week-long on the nest. I found that many of the dainty, small, white terns (*Gygis alba* Sparrm.), whose eggs I had taken away for the benefit of our museum, had continued sitting all day long, seemingly busy incubating, on a round bit of rock, and one, even on the bleached skullcap of its dead sisters. This bird also deserves our admiration in regard to its nest site. Though the breeding birds of Laysan generally do not take much trouble to artfully prepare their nests, this one goes to the extreme. She lays her egg just about anywhere when the mood strikes her. And so, one can find it on the bare sand, on the salt crust at the margin of the lagoon, on the barren rocks next to the surf, and, what is most admirable, occassionally, even in the forked branch of a shrub. There is nothing funnier than to see how the bird tries to completely cover the egg with its body in this uncomfortable position. But she will succeed, in fact, to raise a charming downy chick there, that similarly, must learn the art of acrobatics to prevent itself from tumbling from its precarious perch.

I found it touching when I once observed a tropicbird whose still tiny offspring I removed

to incorporate into our collection. The next day, she adopted the similarly aged young of a noddy (*Anous stolidus* L.), certainly against the will of its parents, to satisfy the desire to fulfill her maternal responsibilities.

Concerning parental love, the majority of the birds we observed displayed admirable selflessness. Once the young had hatched, they could not be frightened off the nest by any threat; with the boobies and the frigatebirds, we had to use considerable force to remove the violently and painfully defensive birds from their nest. The frigatebird had the most noteworthy defense, being a clever and cunning pirate which otherwise did not refrain from swallowing the unguarded babies of weaker birds, even those of its own kind.

Male and female generally take an equal share in raising the young. The parents come back from the sea with pedantic punctuality (in the case of the albatross and the black tern, between 3 & 4 P.M., the tropicbird, between 9 & 10 A.M.), with richly filled crops to feed their little ones. When the young grow larger, they have to be taught the profession, work, and skills of a grownup bird. Thus, we observed daily the terns leading their recently fledged young to the sea. The mother rushing ahead a short distance, constantly uttering its "weide-weck" ("wide-awake" in English, the German is more to the point: "away from the meadow!") call, now encouraging, then warning the young. The obedient little ones would answer with a frail "peep-peep." We could scarcely believe the size and scale of vocal expressions that this bird (and also others) used to express all the stimuli of its emotional life. It not only had numerous different utterances, but its accent was also extremely variable and a trained ear could soon distinguish, as easily as its fellow bird, whether the call expressed a desire for love or hate, a question or a demand, or an encouragement or warning. It always reminded me of a particular northeastern Siberian tribe, whose language contained a word which could express very different concepts depending upon its accenting.

Some of the birds undoubtedly possess a sense of play. Around noon, many of the skilled flyers, apparently just for fun, will rise so high into the air over the island, that they can barely be seen. They circle there for hours at a time. I fully agree with others who have witnessed this phenomenon, that the soaring flights to those lofty heights by the mighty frigatebirds, can even delight the indifferent observer. There is another aerial display that serves solely as entertainment and is even more admirable, not only because of its gracefulness, but also, I hesitate to say, from a psychological point of view. We can see, even back home, great numbers of circling storks. During the spring and summer months on the seacoast, we might even see larger gatherings of gulls circling. But these aerial dances are very plain compared to the magnificent bird-quadrille which we had the pleasure of enjoying on Laysan. During the midday hours on relatively calm and warm days, we saw what began as a mostly disorganized flock of terns, often counting into tens of thousands, become reorganized into the discernable shape of an enormously big cylinder, its lower end near the sea surface, its upper end rising to considerable heights. At its peripheries, thousands upon thousands of birds moved in and out, so that they flew alternately, from one side to the other.

All this commotion took on an ordered appearance, making it look like the well-choreographed turns of a round dance. Aside from the circling movement of the single birds around the surface of the cylinder, the whole bird mass pushed up and down in rhythmic waves, while also proceeding forward according to slight variations in the wind current. It is easy to understand that every one of the thousands of birds described an extraordinarily complicated flight line, yet the whole flock looked rhythmic and harmonic. When the young began to fledge, they were a funny sight to see as they tried to participate in this formation, but most often, blundered and were forced to veer off. It was very unusual to observe that not just the one bird species carried out this flying dance, but was often joined by a substantial number of frigatebirds. Normally, they do not live on good terms with the terns at all, but for some reason they will amicably participate in the game. These two species always formed the great majority of the spiraling flocks, but occasionally, single tropicbirds, white terns and boobies were seen; and sometimes, an albatross also flew with them.

However, bird life is not always that idyllic on the island; often quarrels and fights prevail. Most are occasioned by that highwayman, the <u>frigatebird</u>. In its other habitats, it must procure its food from the sea as other seabirds do. Here on Laysan, I have come to know it only as a robber. When shearwaters, boobies, and tropicbirds return with their crops loaded from fishing, the thievish frigatebirds, spying them from afar, attempt to acquire their quarry by force. They attack their victim with a dashing flight, having a velocity unparalleled by the others, reaching it like an arrow and pinching with their long, scissorlike and hooked bill until the victim empties its full crop to lighten itself. Like a bolt of lightning, the robber shoots behind it, and the tidbits gets buried in its insatiable gullet before reaching the sea in its fall.

It is surprising that the frigates only pinch and nip the smaller birds but never seriously hurt or kill them; otherwise they would rob themselves of their providers. I often viewed compassionately as tropicbirds, having spent perhaps half a day fishing diligently, were forced in the immediate vicinity of the island to pay their tribute to the robbers despite all their skills and efforts, only to arrive with empty crops for their young. They crawled sadly beside their hungry chick, which looked on in surprise at the mother who was forced to delay the desired meal. The chicks becoming impatient, pushier, and more demanding; finally received some rough bill-blows instead of the much hoped for food. It was a sorry day for the family; the chick had a hungry stomach and the old ones had a greater burden.

I want to close the description of the bird world of Laysan with a few episodes from the life of the <u>albatross</u>. During our stay, their very small, quite helpless chicks grew considerably. Behind each tussock of grass, one could see the trusting face of a well-nourished albatross chick, which appeared as quite a comical sight, especially when the downy hood on its head was blown up by the wind from behind. Every one of them looked identical, at least in our eyes, though not for their mothers, who, when returning well stocked from the sea, could soon spot their own little one among the thousands, even if it had

wandered a little instead of waiting at the usual place where its cradle stood. At times, we observed some quite comical scenes, as a number of young would gather around, and beg for food from any albatross bringing it in. The adult would tolerate this for a while, and then, disturbed by the impertinence of today's youth, would raise her head and neck up vertically, uttered a howling call of complaint, and thereafter avenge the vexing crowd with blunt strokes of her bill. Only by doing this, did she get enough room to feed her own chick. Having achieved that , she would crouch down beside it, and then the family could enjoy a few pleasant hours in happy togetherness. The wing quills of the chicks grew gradually and they exercised their power daily , unfurling them and rushing along over the sand, leaping into short flights. At the same time, a yearning for the sea began to awake in them. Every day they pushed closer to it, and it was surprising to observe that, even those which could not see the coast from their location, took the shortest route to it. Once they reached the beach, they did not stop there but trusted themselves to the desired element. Quite often, they had to pay with their lives for this first daring step. One could find the corpses of not quite fledged albatrosses after heavy weather, especially in places where there had been a heavy surf on a steep shore.

To summarize the life of this bird on that island, we are forced to compare it with the human condition. Those that arrive there first may choose for themselves the best places on which they can raise their young easily and safely. Their chicks will thrive successfully and will transition well equipped into adult life (Berlin West!).[4] But the last arrivals, regardless of the reason and fault for their delays, must choose from among the worst places, often the shores of the lagoon consisting of pure salt which, after even a short rain, becomes covered by a sticky, lye-like ooze. Here is where most chick casualties are found, with their plumage ruffled and feet wounded from the action of the concentrated brine. Here is where the highest juvenile mortality rate occurs (as with the most miserable basement tenements of the poorest inhabitants in a big city). But quite often the offspring perish because the parents find the struggle for survival too difficult. They become delayed by storms which drive them far away, and when they finally make it home, they find their chicks dead from hunger or thirst, if not altogether missing, the relentless waves having already prepared for them an early grave. Thus it seems that richness and poverty, luck and misfortune on this earth, whichever it may be, is partially self-inflicted, and partially the necessary outcome of environmental conditions that affect all beings, and that are stronger than their own natural abilities. All must submit to these conditions, for there is no escaping them; no matter how much a higher justice may feel indignant about the situation.

The rest of Laysan's fauna, though very valuable to the researcher, does not have many

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[4]Berlin West must have been a fashionable suburb at Schainsland's time; comparison with the slums follows below (Translator's note).

noteworthy peculiarities of a more general interest. For this reason, I shall only report briefly about it. Seals occur singly but quite rarely on the island. Turtles (*Chelonia viridis* Schn.) however, are numerous on the coasts of Laysan. One can often see entire groups frolicking about in the clear current, especially in such places where the rocky coast has formed a steep ledge. If it is justified to refer to the flight of some birds as swimming, then it may not be altogether unfitting to compare the swimming of turtles to flight, especially when they flutter up and down with their heads through the clear waves. They possess a considerable swimming ability, venturing into the strongest surf without any harm at all. Moreover, I never succeeded to capture them in the water; even when I could tell from the reddened water that my bullet had struck home. They just swam away quietly as if I had not hit them. But this does not seem so remarkable knowing how tenaciously they hang on to life. We discovered with horror that there was no way to kill a captured one. They will even produce life signs when decapitated, or when their hearts have been removed. However, we were able to catch many on land when they crawled up onto the beach at night to lay their eggs, although nowadays, this happens less frequently, because the sea turtles are more cautious than they were before, when human visits were less common on the island.

Those dark, cool evenings when we spent hours waiting for them, crouched motionless, flat upon the sand, often wetted by a higher splashing wave, will become lasting memories. Never before have I been so excited at hunting a noble game, as at the time, when, after a long wait, the eye, which could hardly penetrate the darkness, caught sight of a black mass, hesitating and, with a snail's pace, glided out from among the waves. We had to take care not make even the smallest motion or the slightest sound which might arouse the suspicion of the animal, which is equipped with very sharp senses despite its dull-witted behaviour. Only after it had distanced itself quite a ways from the sea, often after a good hour, did we dare to jump up, hurrying as fast as possible in an effort to throw the colossus on its back, despite the raging threshing it made with its giant fin-feet. When you look in the Museum at the huge specimens that we collected from Laysan, you will understand that I could often not tackle them alone but needed the assistance of my wife. Once turned onto its back the turtle was completely helpless (except for its giant parrot-beak which we had to watch not to approach too closely). But if it had gained enough time to turn toward the sea again, and get its front fins into the water, the power of several men was not enough to restrain it.

Though the turtles came to land solely and entirely for egg-laying purposes, we were surprised when, several times. we caught males. Would they perhaps have been helpful in digging out the deep hollows which would receive the eggs? By the way, I was never able to find such nests complete with contents. And so, I was delighted when one day we caught a turtle containing in its innards several hundred ball-shaped eggs, covered with a white flexible membrane, about the size of those of the domestic hen. We carefully collected and buried them in the sand about two feet deep. I must have found the right depth because all eggs developed further. The last ones which we took from the artificial nest just before our departure, already contained tiny ones, which, when put in water, swam around happily. You

can understand the pleasure I felt then , as a stepfather and embryologist, when I thereafter came into the possession of a complete, and scientifically very rare, material for study of their developmental history.

The sea around the island was crowded with fish of many different species. I have been able to gather a large collection, some of rare and hitherto unknown species (18). Most pleasing to the eye are the kind that are adorned with lively colors, observed elsewhere by us only on flowers and butterflies. They dash around the coral rocks and are therefore also called, coral fish. The curious pipefish was present in schools and provided us with many tasty dishes. But, we carefully avoided eating the poisonous flesh of a remarkably blown-up fellow, the porcupine fish.

Corresponding in numbers to this multitude of smaller fish, were their enemies, the sharks (*Carcharias gangeticus*, and *Carcharias* sp. ?). They were really so numerous at one place on the reef which they had chosen for their residence, that we could count hundreds of them at low tide, when they swam to and fro right under the surface with their dorsal fins sticking right out of the water. Quite a number of them are now hanging in our Museum and, upon viewing them, one is easily convinced that there are some really big members among them. We caught them, mostly by wading up to our hips into the water, and then hurling a harpoon on a line into the nearest one. If it hit its target it became highly advisable to immediately climb up onto a coral block, because as harmless as they appeared before, a great frenzy broke out soon followed. I firmly believe that among the sharks, as is also reported about the tiger, there are special man-eaters, which prefer catching this noble prey after they have tasted its tender meat the for first time. Apparently, none of the sharks had yet tasted it, because, although we refreshed ourselves every evening with a swim in the lukewarm water, we remained unharmed. We also heard that during all of the time that the guano workers visited the island, no shark attack on humans was ever reported. By the way, the shark disappears from the vicinity of the island during some winter months, when it presumably descends to deeper waters to deposit its young.

To the contrary, another leviathan, the ray (*Aetobatis Narinari* Euphras.) with its broad, square, platelike fins, appears only for a short time off the coast where it deposits its two young off in the shallower water. These young look very amusing, having a thin tail, which is many times longer than their body. They presumably inhabit greater depths where they feed on mussels using sizeable bony mandibular plates, which they have instead of teeth. During some August days, when the trade winds had stopped and the sea looked like a mirror, except for the ceaselessly pounding surf, we noticed a sudden foaming of the water at the margin of the reef, quite far out; they were skates, ascending from the depth and lashing the surface of the sea with their huge winglike fins. We quickly launched a boat and tried to approach with silent beating of the oars, to within harpoon-throwing distance. Quite often, we missed but on a few occassions, we were able to bring home this heavy fish, often weighing several hundred kilograms. I was fortunate beyond all expectations when, in the

last catch, I obtained a pair of recently hatched, newborn young as well.

With this, I will terminate the discussion of the fauna and want only to note that the lower land animals are poor in species but extraordinarily rich in numbers. For instance, a simple gray moth (19) appears, at times, in swarms of several thousand individuals, providing almost the sole food supply for some of the land birds (for example, *Acrocephalus*).

It would be wrong to imagine that the island is only attractive to the natural scientist. On the contrary, every friend of nature would find unexpected enjoyment in it, if he was also able to recognize its beauties as they are displayed in other than "the usual old garment." Truly, it is a hard beauty, that surrounds us here! The impressions, called forth by the roaring of the surrounding sea, the white sands, the pale green vegetation, all remind us somewhat of the magnificence of the desert. The colors that we are able to observe on the island, in the sea and on the substrate, have a wonderful splendor. While as a rule the whitecaps contrast blindingly with the dark blue sea, when the sun stands high and the tide is low, in the places where the sea bottom is sandy or at least not covered with plant growth, the water shifts into a lovely green color, as the bottom reflects back the intense, penetrating light. When at sundown, the clouds of the western sky radiate a golden, violet, yellow or even greenish light, while the eastern horizon takes on an almost threatening blue-black hue, here and there mellowed to light blue or dainty pinkish, words can only touch upon the nuances of the true colors. The night sky was also especially clear and beautiful, perhaps because the white sand reflected and magnified the moonshine, making it seem almost like daylight, or perhaps the stars shone against the dark ground. Even the Milky Way here looked like a fully lit-up cloud: its mild glow brightening the sky, and even the famous Southern Cross faded before its beauty.

The esthetic impression which the island commands is quite sobering and really very grandiose, perhaps also magnified by the thought of the loneliness and solitude that is this tiny grain of sand island amidst the vast watery desert. It was just exactly this that had considerable influence on our spirit. I never understood so well Rousseau's exhortation about returning to nature as I did right here. Here, we learned to understand anew the language of nature, which rarely rings in our ear amidst the noise of culture and civilization. Here we feel like we are back in our true home, withheld from so many of us during our peregrination through modern life. Every one who, like me, enjoyed the good fortune of delving for a time in such a solitude, only comparable with what we find in the desert, would agree that the impressions acquired here would last for a lifetime. The thoughts we had there were more serious, and even perhaps deeper; the pettiness of everyday life disappeared and the dissonances resolved themselves.

As I already mentioned, we enjoyed in many odd ways the hospitality of the company since we left Honolulu.

We lived next to the inspector's building, in a neat room constructed of boards. A small space in the "lighthouse" served as our laboratory. The numerous chests and boxes of the

travel equipment stood outside, in the open, covered by tarps. Our rich and good fare consisted mainly of canned food; yet the tasty bird's eggs, the gourmet "kolios" (*Numenius tahitiensis* Gm.), and fish and turtles added the necessary fresh nutrition. Respecting the otherwise very highly esteemed turtles, I must note that they lose their high desirability after having been consumed frequently; on Laysan a variant of "toujour tortues" as an "aside" was at times well justified. Since there was no consumable plant on the island, we were forced, especially in the beginning, to get used to the lack of any kind of fresh vegetable or fruit.

The drink situation was not as good as the food. Water on the island is brackish, one relies solely on rainwater gathered from the roofs. Since they had been freshly pitched just before our arrival, one can imagine that our drinks were not exactly tasty. At times, when we were sitting at our work and felt unbearably hot, we found pleasure in elaborating upon the inhumane idea of how nice it must have been in the chilly halls of the Löwenbräu Cellar in Munich. To top it all, at the beginning of our sejour, a very long drought prevailed, which had already killed almost everything green on the island. Little water remained at the bottom of our tanks and washing etc. with fresh water ceased to be possible early on. We were already anxiously thinking about the future. How we rejoiced when, one night, we awoke to the drumming of heavy raindrops on our corrugated iron roof and found the containers filled to their brims the next morning.

In the beginning of our stay, I would spend the early morning hours strolling across the island, bringing materials, birds, etc. for my assistant, i.e. my wife, to work on. Day in and day out, she would painstakingly prepare the specimens truly by the sweat of her brow as long as daylight lasted. Later in the morning, I would rush to somewhere on the reef and spent many hours half or totally submerged, weeks at a stretch. I couldn't believe that it was possible for this work to exhaust even a strong body. I mostly observed, after coming out of the lukewarm water, that I had to throw myself totally exhausted onto the sand. I believe now what someone said to me later in Honolulu, namely that beginnings such as this almost always lead to a heavy, or even deadly, fever.

We should not at all suppose that the activities of a busily collecting naturalist are easy in the tropics. Totally apart of the work in the water (which by the way was absolutely necessary for it was impossible to catch anything with a net amidst the pointed coral branches), the novice needs a considerable degree of strong will to amble about the totally shadeless island in the burning heat of the sun, wading through deep sand, breaking through, kneedeep into subterranean burrows. Every activity with which one is used to having helpers, must be carried out with one's own hands, in the open without shelter, from soldering tin cans stuffed with specimens, to hammering steel bands onto the chests, filled for the long transport across half the globe.

There was one circumstance that nearly brought us to despair while working. I'll not lament about the incessantly buzzing fly swarms, nor of the inch-long cockroaches, which

not only ate our candles and bookbinding covers while we slept, but also our very own fingernails. Instead, I'll complain about an insect (*Dermestes domesticus* Fb.), which perhaps does not occur anywhere else in the world in such multitudes but which housewives find once in a while in their pantries, a small blackish-brown beetle: the carpet beetle. Castaways probably introduced the first ones to the island. Since they have an unending food supply here in form of bird carcasses, and a lack of any population of insect-eating birds to keep them in check, their numbers have increased into the billions. We had hardly finished the tiring work of preparing a bird specimen, poisoning it with three times as much arsenic as usual, when columns of this tiny pest came dashing over to it, trying to annihilate our work. Too often, they succeded because the drying of the skins was retarded by the humid sea climate, and the poison lost its power on the areas that remained wet. On days when the trades did not blow with their usual force or stopped entirely, and the oppressing air alone was hard to bear, their plague became altogether intolerable. Before, the wind hindered their flight, but now they would come streaming into our habitation, like entire armies, and even attacked us, considering our hair to be something palatable. During the evenings of days like these, we had to literally sweep out the hordes from our stores. What these tormentors had not ruined of our preparations, were eventually consumed by the ants; [a quite tiny species (20)] which, once their pioneers reconnoitered the whereabouts of our treasures, rallied in whole armies to the war of annihilation. I often found my wife in tears over the lost efforts. In the end, the only thing left for us to do was to hang all bird specimens (there were hundreds) singly on wires which were poisoned with mercury, making even this narrow bridge impassable to them. Evenings were mostly devoted to rest after the days labor. The main meal was eaten about sundown, and thereafter, we would sit quietly in front of our cabin. The nights were always cool and pleasantly refreshing. These evenings of rest were among the nicest times we spent on the island. Since we had a clear view of the sea and the western horizon, every evening we would admire the diversely changing, yet always equally beautiful, color display conjured up by the setting sun and the reflexions in the sea, a display which was not supplanted by the dark night as quickly as elsewhere in the tropics. There was on Laysan, a real twilight, when the sun had just finished glowing and it gradually became dusk; the evening star lit up with such brightness that tall objects cast a shadow against its light. These were the moments when our thoughts rushed homeward. We would intentionally not discuss our children in order to decrease our longing for them. Yet, how ardent was our unspoken wish that the same benevolent star, which beautified our evenings, would smile at the other side of the earth on the small beds of our two little ones, and awaken them to a new day filled with joy and good health!

As nightfall became darker and visual stimuli became weaker, those for the ear increased. The surf sounded gentler becoming a monotonous rhythm; from above, one could heard the cheerful call of the never-roosting terns, and all around us, the wailing moan of the shearwaters resounded. All foreign sounds, even the music of the Portuguese chime of the inspector, which sometimes played wild and at other times melancholy tunes sounding very strange to our ears, contributed to making these nights feel even more peculiar.

Not far from us, a simple cross stood over a lone grave. Some years earlier, a man was left behind to watch the properties on the island during the winter, as opposed to the multitudes which are now left to guard them. Seven months later when the next ship returned, he was found in the same cabin which we now occupied, dead, in front of his diary which had entries up until 14 days before he was discovered. They buried him right there on the beach. Shortly after our arrival, as we looked with sadness at the quiet grave, the dark outlines of the cross filled me with horror. After the barque left the island having brought us here to fend for the next months entirely for ourselves, my wife came down with a serious disease. How horribly the anxiety gnawed me as I imagined in the twilight, a second cross there! The strong physique of my wife overcame the sickness though, and in eight days, the danger was over.

We had counted on about two months between the time of our arrival and the return of the ship. These months had come and gone, and we searched the horizon daily, but in vain, for the appearce of a sail. Thus, the last part of our stay became less pleasant, since our work was mostly finished and there was not enough to keep our minds busy. And so, after many weeks passed, we began to fear that the ship had met with some disaster. I t had happened just a few years earlier to the "Wandering Minstrel" as it became stranded on neighboring Midway Island. The captain and his wife, who were the sole survivors, were forced to live for 14 months on albatross meat in this entirely barren and, compared with Laysan, quite desolate island, until they were rescued entirely by chance. Finally, one afternoon, as I again stood at the lookout point, I noticed a white point appearing on the horizon which could be nothing else but the sail of our barque, shining in the afternoon sun.

Even the great joy occasioned by its arrival became somewhat dampened. From the moment that the ship appeared before the island, the weather changed, although up until that time it had been quite steady. The trade winds stopped, replaced by winds from different directions, making a landing on the island risky, or even impossible. It was a phenomenon that we had never observed before during this time of year (September); it normally occured only in the winter months. The winter on Laysan generally differs from summer mostly in its lower temperatures (21). Our past experience of the island's constant and temperate summer weather, was that it did not pose any danger, even to the Guano Company's larger visiting ships. This year however, as noted, the weather deviated from the norm. The barque that I sighted wanted to land at the "landing" on the west side of the island, but the wind and weather became so bad that it had to retreat, and much to our regret, was forced to cruise in front of the island. Finally on the third day, the captain succeeded, with a beautiful maneuver, to anchor at just the right spot and secured the ship. But the weather did not improve; it was either stormy or dead calm. When the mighty western swell was not held back any more by the eastern trade wind, it found its way unobstructed and caused the ship to roll to such an extent, that the sails almost touched the water every time they were hauled over. No wonder we rushed to the window daily, at the crack of dawn, to see if anchor and

tow had held, or perhaps to see if our ship was perched upon the reef. But it held its anchorage steadfastly, and even while being loaded by the guano scowl, although this was accomplished at a slower and more difficult pace than usual.

On the evening of September 22nd, we received an unexpected message from the captain, saying that we must board at once. He wanted to sail away immediately before the masts were ruined by the extremely strong rolling action. We rushed to get ready, gratefully shook the hands of the inspector who would stay with his family and a dozen Japanese (all others came with us), and left in the small boat, as the last rays of the setting sun once again displayed the unique splendor of the island. Anyone who knows what it's like to climb the rope ladder up the side of a violently rolling ship, will understand how relieved I felt when I saw my wife safely on deck.

But our departure from the island was to be further frustrated. After we boarded, the weather became completely calm, and for better or worse, we were forced to lie around almost two full days.

A few people who never get seasick, might find the sojourn on a heavily tossing ship pleasant, but almost no-one could find any pleasure in remaining stalled, at anchor, while being rocked to and fro from deck to water level and back again. Under these circumstances, there was no way for us to get any sleep for two nights. Finally, 40 hours after we have boarded, a favourable current of air, which could drive us away from the island, arrived. It was cleverly utilized, the tows were untied from the buoys, the anchor was weighed and we floated happily away from the menacing reef. From the top of the "lighthouse", the people remaining on the island, waved the last greeting of the flag. We now understood completely the meaning of the kind of courage that was required to stay there in total solitude for 6 to 8 months, completely separated from the rest of the world.

As the lovely island gradually disappeared from sight, we were happy that the first hour of the journey went so well. But I was especially moved when I read later in the diary of the inspector, about September 25th, 1896: "It was lucky that the barque got away from the island yesterday; today it would be sitting on the reef; the surf is as high as a house and our harbour a single white foaming mass."

In our hope of making the return journey, if not in the same time as our outbound voyage, since the trades now blew against us, but perhaps in twice that time, we were bitterly deluded. We needed four entire weeks to put behind us that approximately 890 nautical sea-mile stretch of ocean. This was not unusual, since the weather hindered us with tiresome regularity being either calm or stormy, but always blowing from the wrong direction. We had to exercise great patience! Another form of sailor's virtue was to eat salt meat; we had plenty of opportunities to practice this virtue. Our normally pleasant memories became somewhat disturbed by the Japanese ship's cook, Matsuda. There were times when I really

wished that the very tolerant captain would act upon his threat to "throw him before the headwind." For example, one day this peculiar culinary artist ran short of yeast. He continued baking though, as usual, which resulted in the bread having such a solid consistency that, in the event of carelessly dropping it, it would have been falling like a stone and crushing our tabletop. We set our highest hopes on a few stately roosters which we had visualized with longing glances, for weeks at a time, that they would serve to us for a Sunday meal. But the "son of the rising sun" cruelly betrayed us. The *pièce de résistance* of his art consisted of an endlessly thin gruel, in which lonely remains of the deceased birds swam.We attempted to substitute for the missing enjoyment theoretically. While confined in my childhood to a strict and tedious diet, I found solace in reading Voss' "Louise" and amused myself by vicariously consuming the tasty meals that the good minister's family often enjoyed. Our reading material on the ship was not that classic. Fortunately however, my wife found at least one magazine from home in our cabin, which in a philanthropic way, described in detail a number of fine dishes to be enjoyed by ladies. We often read aloud these pleasant tidbits to one another, and thereby, distinctly awakening in us the most soothing of gastronomic feelings.

These small deficiencies were nothing compared to all the friendliness we received. How can I find words to praise you, you most excellent of all captains, Andreas Barber! How we rejoiced every evening when you amused us with your fabulous storytelling talent and your inexhaustible humour; how you amused me especially, allowing me to temporarily forget my bed of pain. I suffered during the whole journey, from rheumatism and furunculosis resulting from my diving work and various kinds of overexertions. Skits about the instructive activities of the honourable professors Breusing and Romberg were alternated with stories about the hilarious pranks of Messrs. Novice Sailors, and the more serious adventures of a sailor life. But when heavy weather arrived, and it came often, we felt snug and calm under the guard of our captain.

Little else can be recounted of this journey. We did not expect, as fictional stories would have us believe, that the tropical sea would be so richly bountiful. The part of it which we plowed through was like a desert. Only now and then would a flying fish dart across our bow, soon to fall back, fluttering, into its element. Once, we were able to observe the exciting hunt of a dorado (*Ciryphena* sp.?). This beautifully shiny raptor fish was chasing a flying fish. These apparently evolved their flying ability for the exact purpose of escaping the pursuits of their voracious relatives. Even this skill did not always help them. The flying fish had barely risen up from the surface of the water, when the dorado, with a forceful leap, also made its appearance. Although it lacked the ability to pursue its prey in the air, it could locate the exact spot where the prey would fall, arriving there by swimming in a straight line, almost paralleling the flight of the pursued. This was repeated several times, the flying distance of the pursued becoming shorter and shorter, the leaps of the predator, wider and wider, as it chased its prey like a tiger. After a few minutes, neither of them showed up anymore. The flying fish had found an early grave.

One afternoon when complete calm prevailed, we saw one of the mighty octopuses. Though not as big as the floating island in the legends about Krake the sea monster, still, it must have measured 7-8 meters in diameter.

Since calm weather often prevailed, I was able to use the net to collect those tiny, transparent beings that often filled the water in stupendous numbers. Most of these barely visible plankton (22) animals were able to glow so brightly at night, that when a great mass was gathered in the net, one could read boldy printed letters by their light. Often, we also found the tiny insect (*Halobates sericeus* Eschr.) in these catches, a close relative of the water strider, which we see gliding away on the surface of our creeks and ponds and which adapted to life on the vast open ocean.

Our longing for land increased gradually as we neared it. Again, we sighted birds more often, but the resentful wind somehow always retarded our passage. Then, on the 27th day after we started, the vague contours of a mountain range emerged from the cloud masses on the horizon. This was the precipitous coast of Kauai. The next morning saw us in the immediate vicinity of the pretty Koko Head of Oahu. In front of us towered the silver-shiny forehead of Diamond Head which still hid Honolulu from view. To the right, a black, white & red flag stuck out from the dark green coppice of coconut palms in the Isenberg property of Waialae; it was hoisted up and down three times! We were astounded that the first welcoming greeting came from Germans. Soon we had a small steamer at our side and in a short while, were able to hop on land. The following day was the beginning of a southern storm. Had we not landed then, we would have had to cruise for another week within sight of Honolulu.

Years have elapsed since then, but we still experience in our dreams those extraordinary times. In our minds, we can see the spray of the mighty surf; inhale the intoxicating fragrances of the lovely flowers; and hear the songs of our bird friends. The feelings we have are of a longing, yearning desire to be on that tiny island amidst the imposing solitude of the ocean.

Appendix

The scientific results from my collections will be published (and have already been partly published) by the various collaborators; thus I will restrict myself here merely to a few data.

The numbers (1 to 22) you find here and there in the previous text refer to the bold numbers of the notices that follow.

1) p.1. The islands lying NW of Kauai, enumerated from E to W, are as follows /Compass directions shall be abbreviated by the translator/ (elevational data in English feet following the English Admiralty Chart of 1895; cf. also the few data in: Report to the U. S. Bureau of Navigation, December 1867, by Capt. Wm. Reynolds):

1. Bird Island (Nihoa); extremely steep, entirely volcanic rock, its highest elevation is 903 ft; about 3/4 naut. mi. long and 1/2 naut. mi. wide, entirely without coral formations although on the chart there is often a remark at the depth locations such as "corals." For example, "at a depth of 21 fath off the N of the island 1/2 naut.mi. from land; at 22 fath to the E 1/2 naut. mi. from land; at 11 fath to the S 1/2 naut. mi. from land; also at 23 fath likewise to the S 1 naut. mi. from land."

2. Necker Island, a longitudinally stretched, 1/2 naut. mi. long, 1/8 naut. mi. wide and up to 300 ft high volcanic rock. In the N the chart indicates coral rocks very near the coast at a depth of 2 to 8 fath. I do not know whether they are part of a living reef.

3. French Frigate Shoal; an isolated volcanic rock of 120 ft height and several lower sand banks which are situated in a large lagoon surrounded by coral reefs.

4. Gardiner Island, a sugarloaf-shaped, 170 ft high volcanic cone, on the NW corner of which towers one more, isolated, volcanic rock. Apparently without coral formations.

Whereas, with the above islands, the volcanic rock is still visible, this is not the case with the following ones. These are pure coral islands.

5. Maro Reef. An about 7 naut. mi. long, 6 naut. mi. wide reef which does not reach the water surface. Whether it is a coral formation (which is very likely) or not, I do not know.

6. Laysan, 25 ft high.

7. Lisiansky, about 50 ft high; it is similar to Laysan in its composition in that it is a compact coral island girdled by a strand reef. It seems to have no water-containing lagoon.

8. Pearl and Hermes Reef is an atoll formation with a perimeter of about 42 naut. mi., with 4 or 5 lowly sandbanks lying in the enclosed lagoon.

9. Midway Island. Likewise is an atoll formation. Inside of the reef (18 naut.mi. in perimeter) there are two elevated areas of which the one, Green or Eastern Island (5/4 naut. mi. long, 1/2 naut .mi. wide and up to 15 ft high) is covered with thick vegetation (*Scaevola*, *Eragrostis*, etc.), the other (1 1/2 naut. mi. long, 3/4 naut. mi. wide and up to 57 ft high) is almost without any plant growth.

10. Ocean Island, the last of these islands, (at 28° 24' N. Lat., and 178° 27' W. Long.) is an atoll formation very similar to Midway, with a reef of almost 15 naut. mi. in perimeter.

Morell and Beyer Islands which are also on the chart, cannot be found nowadays (Dr. Averdam, 1898) and seem not to exist.

Apart from those found on Laysan, I was only able to study, among the above islands, a few rock samples from Necker Island by the courtesy of Dr. Averdam. This island consists only of eruptive rocks through which basaltic threads and veins pass. On some slopes there is a curious iron- and clay-phosphate soil with about 40% phosphoric acid and very little limestone. This occurs in relatively large amounts upon the volcanic rock and is a product of decomposition (of bird excrement and bones). The other volcanic islands, Bird I., French Frigate Shoal and Gardiner I. are geologically and mineralogically similar to Necker I.

2) p.8. These tubes, stacked in sand, often reach the length of several meters while their diameter can be up to 5 cm and their lumen up to 2.5 cm. Often, though not always, they are dendritically branched. They could not be lightning tubes since the sand kernels are not melted together.

3) p.8. In the N of the island, at the bottom of the slope of its highest elevation, I excavated at a low site richly covered by growth of *Scirpus laevigatus*. According to my information, there should have been a coal deposit there. Beneath a humus layer I found first sand, then a hard mass of marble-like material, and finally, in not inconsiderable amounts, peat (mixed with some sand), consisting of long plant remnants in layers (*Scirpus*?). I could not penetrate this mass of peat deeper than 1 to 1 1/4 m because of the rapid flooding of (slightly brackish) water.

4) p.8. The analysis of some probes of exploitable guano yielded the following proportions of phosphoric acid and limestone: 1). Brown guano (lying on the surface) 11.5% P_2O_5, 48.64% CaO. 2). Light colored guano 36.99% P_2O_5 33.30% CaO. The rough Laysan guano that was freighted away contained on the average 25-30% phosphoric acid.

5) p.8. It appears that these brimstone pieces have been deliberately collected by albatrosses, perhaps to stimulate their digestion. Smaller pieces have been also a part of the food mash with which the older birds feed their young. Yet, I would not want to state that all the brimstone found on Laysan had reached the island in this way. During my stay, I never found any pieces on the beach, they were always in the interior of the island, partly on the surface, partly in the guano pits.

6) p.8. 1,000 cc water taken from the lagoon of Laysan in August 1986 contained: evaporation residue 165.8 g, lime 2.9 g, magnesium 10.3 g, SO_3 sulphuic acid 11.2 g, chlorine 86.7 g (corresponding NaCl 142.4 g). For a comparizon I submit that water from the salt lake Moanaloa near Honolulu, taken in June 1896 contained chlorine 139.3 g, corresponding NaCl 229.4 g. Besides, the water is very rich in magnesium. In spite of this high saline content, I also found *Artemia* here. The organisms in the lagoon of Laysan mentioned above on p. 20 are the only ones occurring there. It goes without saying that coral formations do not occur there.

In the surroundings near the lagoon, where there is already plant growth (*Cyperus laevigatus*, etc.), in addition to an amphipod, the tussocks of these plants are inhabited by an earthworm (*Pontodrilus ephippiger* Rosa var.n. *laysanianus*).[5]

7) p.9. Both algae which occur in the lagoon represent not only new species but new genera. *Chondrocystis Schauinslandi* Lemm. nov. gen. et spec. forms hard, cartilagelike, sometimes several feet thick, more or less rosy colored masses. It occurs in the water and also on the shore of the lagoon as long as their is moisture. In this latter case, the alga is mixed with crystallized salt and thus thrives here in a completely saturated brine solution. The second form, *Coelosphaeriopsis halophila* Lemm. nov. gen. et nov. sp. consists of hollow spheres that float in the water of the lagoon.

8) p.9. On the driest strands of the lagoon which are only flooded at high water, one finds rock fragments which, in places, are peculiarly kidney-shaped, in other locations, they form coherent rock benches, up to 45 cm high. These benches consist of almost half of Calcum carbonate, besides having a very large content of magnesium. If the future, thorough analysis shows that this rock has a dolomite-like character, this would then be evidence that in waters with strong magnesium content, dolomite-like rocks are being formed even today.

9)p.9. This "beach canal" separating the reef from the island, is missing only in some

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[5]Michaelsen, Oligochäten von den Inseln des Pacific. Zool.Jahrbücher Syst. 12th Bd. 1899.

parts of the S and SE side. The biggest opening of those which break through the reef (mentioned on p.9), is on the W side, hardly 3/4 naut. mi. away from the NW point. This is now almost exclusively used for mooring of the guano-loading ships (especially since, with the dominant NE trade winds, there is almost always calm water here). These ships find, at a distance of not quite one naut.mi., good anchorage in 8-12 fathom water here. There is a second, similar, passage on the opposite (E) side. In addition, there are two smaller ones on the S and N side.

To date, unfortunately, there are not enough depth measurements in the proximity of Laysan. Still, according to the measurements of Capt. Brook in 1859, there is a 5 naut. mi. wide bank with 14-20 fathom-deep water outside the reef, but nearby, the bottom seems to sink into the abyss quite abruptly. Capt. Barber (Bark H. Hackfeld) measured in 1896, off the W of the island, depths of 45 fath , 5.5 naut. miles off 5.5 naut. mi. from land, and noted depths beyond recording limits 6.5 naut. mi. off the SW and 6 naut. mi. SE of the island.

10) p.10. To date, only the larger forms of sea shells from Laysan's reefs have been identified (by Prof. von Martens), therefore, I am omitting a listing of these. "Most of the species identified so far, are widely distributed in the coral reefs of the Indian and Pacific Oceans. Some, already known from Mauritius and Madagascar, testify to the homogeneity of the fauna of these coral reefs. *Strombus aratrum*, *Cypraea tessellata* and *C. sulcidentata*, *Nerita picea* and *Littorina obesa* are more rare and seem to be restricted to Polynesia and, are all absent already in the Malayan Archipelago.The occurrence of *Latyrus nodatus* Martyn is very interesting since its home was not well known until now, although it appeared in the European collections already from Cook's material, though rather rarely."

Of the Opistobranchs[6], numerous *Aplysias* occurred on the reef, up to 20 cm in length. I also found there the very interesting, hitherto hardly known *Chelidonura elegans* Bgh, further pleasant *Hexabranchus lacer* and *Samta annuligera* Bgh., nov. gen. et spec.

Of Polyclads[7] *Thysanozoon Brocchii* Grube was not uncommon on the reef.

11) p.10. Major Th. Reinbold worked up my algal collection.[8] I collected the following sea algae from Laysan:

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[6] R. Bergh, Malakologische Untersuchungen, 1899.

[7] M. Plehn, Die Polycladen der Sammlung Schauinsland. Zool. Jb.Syst. Abh. Vol.12. 1899.

[8] Abh. Nat. Ver. Bremen, Vol. XVI., Issue 2..

Ulva rigida
Halimeda opuntia
Dictyosphaeria favulosa
Microdictyon umbilicatum
Caulerpa racemosa
C. pinnata
Turbinaria ornata
Sargassum polyphyllum
Hydroclathrus cancellatus
Ectocarpus simpliciusculus
Stypopodium lobatum?
Microchaete vitiensis
Liagora coarctata
L. valida
Laurencia obtusa
L. vaga
Amansia glomerata
Polysiphonia polyphysa
Ceramium Kützingianum
Amphiroa fragilissima
Corallina Sandwicensis n. sp.
Lithothamnion sp.?
Dictyota acutiloba

The single calcareous segments of *Halimeda opuntia* occurred in such masses that, mixed with foraminifera, they formed considerably large calcareous deposits. Lithothamnium */sic/* spec. is very important to the growth of the reef. It covered the dead coral branches with a thick calcareous layer.

12) p.11. Besides the common *Octopus* species of Laysan, one can also find the cephalopods (Identified by Pfeffer) *Ommastrephes oualaniensis* Less. and *O. Sloanei* Gray, as well as *Onychoteuthys Banksii* Fér. The last three species form the main food of the albatrosses, at least during the period during which they feed their young. Their feces consisted almost entirely of cephalopod beaks. Even the *Sula* sp. fed their offpsring with digested cephalopods, although later, also with fish.

13) p.11. The spiny lobster of Laysan is *Palinurus japonicus* de Haan. Apart from this, the two most common decapods are *Grapsus maculatus* Cal. and *Grapsus tuberculata* Lam. *Scyllarus Sieboldii* de Haan, *Carpilius maculatus* L., *Calappa hepatica* L. and *Lophaactaea actaeloides* A .M. Edu. are not rare either. (Dr. Lenz worked up my crustacean material.)

14) p.11. The growth of corals on Laysan — we are almost at the northernmost limit of reef-forming corals here — seems to me relatively slow compared with the more southerly situated coral islets of the Pacific (at least in the present developmental period of the island) and likely contributes, although slowly, to the growth of the reef. Calcareous algae (in the first place), mollusk shells, Serpula tubes, etc. have, in their totality, contributed at least as much to the increase of the calcareous deposits as the corals have.

15) p.13. Of the limestone rocks I found and collected on Molokai, two consist of a peculiar conglomerate rock which is made up predominantly of large, well preserved coral skeletons, as well as marine mollusk shells and opercula (of *Turbo*, *Trochus*, etc.) and even including rounded basalt fragments.

My findings may disprove Agassiz,[9] who, up to now, denies a more considerable rise of the Hawaiian Islands and also does not believe that Dana's[10] data demonstrate even a slight rise of these islands. The rocks from higher elevations (up to 670 ft) show an even, finely grained structure without microscopically documentable coral remains. A limestone layer from 400 ft elevation is very peculiar as it is apparently a freshwater deposit containing well preserved fossil *Achatinella* shells, as well as a great deal of preliminarily not identifiable tiny freshwater or land mollusk shells. It is interesting that two samples of the limestone collected on Molokai contain human footprints (of a grown-up and a child) which were apparently chiseled into the rock by the natives long ago.

16) p.15. According to the preliminary identification by Dr. Bitter, Bremen, the flora of Laysan consists of the plants listed below. I can only add to this list a few notes about habitat, etc. Their distributional data are from W. Hillebrand.[11] As for the rest, I refer to the forthcoming publication of Bitter.

1. *Lepidium oahuense* Cham. & Schl. [*L. bidentatum* var. *o-waihiense* C. & S.] There was only one specimen of this plant on the E side near the beach. It was a small stunted bush of 30 cm height, its lower woody stem about 8 cm wide. According to Hillebrand, it occurs on all Hawaiian islands in the lower zone, from the coast to 2000 ft elevation.

2. *Capparis Sandwicheana* D.C. [*sandwichiana* DC.]. Approximately man-high bushes are numerous on the W side of the island not too near the beach, but not far from it either. Blooming time begins in early May. The splendid, fragrant flower lasts for only one night on Laysan. It opens shortly before sundown and is already withered shortly after daybreak. Though the flowers are numerous, one rarely finds its fruit (lack of pollinating insects?). Only a few exemplaries develop fruit, on most, none can be found. According to Hillebrand it is numerous on Kauai along the coast, on dry lava fields. Otherwise, it also occurs on the Paumotu Islands and on Matia near Tahiti. On Kauai the plant is much lower than on Laysan (only 2 to 3 ft high).

3. *Portulaca oleracea* L. [*P. lutea* Sol.]. In places, this plant forms mats, although, it primarily grows solitarily, presenting a cushion (of 20-40 cm height, 3/4 to 1 m diameter)

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[9] Agassiz, Alex 1898. The coral reefs of the Hawaiian Islands.
[10] Dana: Coral and coral islands. New York 1874 and 1890.1.to 3.edition.
[11] W. Hillebrand: Flora of the Hawaiian Islands. Heidelberg 1888.

using the numerous side branches which branch off the heavy, woody, main stem. It occurs only in dry locations, never in moist ones and avoids loose sand. I found the first flowers in August. These remain open only during the hot hours of midday, otherwise they are always closed. They are so frail that they wilt immediately after being picked, and so, I had to press them immediately. The plant is, more than likely, identical to *Portulaca lutea* Sol., which is described from the Viti Islands and according to Hillebrand also occurs on some dry, rocky places near the sea on Oahu.

4. *Tribulus cistoides* L. Occurs almost everywhere on the island, especially in sandy areas between the single *Eragrostis* bunches. It forms uniformly sized rosettes of 1 to 2 m diameter. Stems and leaves lie flat against the surface, so that the whole plant rises only a few cm above the ground. The big, rigid thorns of the fruits were often pernicious under our feet. According to Hillebrand, it occurs here and there on all Hawaiian Islands on the coast and lower plains (even on Midway). It is a widely distributed plant of American origin, found on most low coral islands of the N. Pacific.

5. *Sicyos hispidus* Hbd. [*S. atollensis* St. John]. Not uncommon on the brackish pond of the southern guano field.According to Hillebrand it occurs on Maui.

6. *Sicyos microcarpus* Mann. [*S. nihoaensis* S. John], occurs singularly on the margin of the lagoon climbing on the *Cyperus canescens* which grows profusely there.

7. *Sesuvium portulacastrum* L. Individuals of this plant are standing alone, only occurring in the low-lying, yet mostly still dry, salty soils in the vicinity of the lagoon. There, it grows profusely and builds, in the company of *Heliotropium curassavicum* and *Cyperus laevigatus*, the only vegetation on this part of the island. It forms a thick, about 15-20 cm high cushion in the absence of any other plant. Its bluish-red flowers open only during the hot midday hours, I never noticed a blooming specimen during the morning or afternoon. It has a peculiar, aromatic fragrance which totally permeates those parts of the island where it occurs.

8. *Lipochaeta integrifolia* Gray. Occurs where the flat strand of the lagoon ceases and is supplanted by the sandy soil characteristic of the rest of the island, it forms, so to say, the transition between the three plants occurring there (from No.7.) and, the grasses and *Chenopodium* thickets which grow especially luxuriantly just at this border strip. It is mostly an herb, although older specimens may have the appearance of a bush, elevated to form a 60 to 75 cm high half-dome, covered with leaves and flowers, the thick tangle of which may reach one to two meters in diameter. This tangle was so thick and sturdy, that young albatrosses often chose to roost on top of it. According to Hillebrand, it occurs in sandy soils on the coasts of Kauai, Oahu and Maui, although its branches do not grow over one foot in length there.

9. *Scaevola Koenigii* Vahl. [*S. taccada* (Gaertn.) Roxb.] is restricted to the beach zone f the island. Luxuriant on the W side, more stunted on the E.side, it forms a bush which,

although only 1/2 to 1 m high, can reach a very considerable diameter. Individuals standing alone form a flat, uniformly leafed dome of 4-5 m diameter, reaching to the ground. The branches lying near the ground remind us of elfin woods; one can commonly see runners that creep several meters tightly over the sand. For the most part, the leaves form twirls which close in the evening. The small white flowers have a pleasant, although not very strong fragrance. Hildebrand: It is widely distributed in Polynesia, the coasts of tropical Asia and its islands. 4-6 ft high.

10. *Solanum laysanense* Bitter nov. sp. [*S. nelsoni* Dunal]. Is restricted to only one locality on the northern side of the island, there, on the sand dunes near the beach, it forms a lowly, ground-hugging shrubbery which looks shabby and rises barely more than 25 cm above ground. The circular leaves are covered with gray, feltlike hairs, the small flower is bluish and the fruit is pea size. Blooming season begins at the end of August. There are only about a dozen specimens on Laysan. I observed, from photos, that this plant seems to occur, in masses and profusely, on Pearl and Hermes reef, where it covers the ground, in some places, with a low, thick shrubbery.

11. *Ipomaea pes-caprae* Sw. occurs everywhere on the higher areas on the beach. One often finds specimens creeping distances of 6 to 10 m on the sand. I found it in bloom at the end of June; by the end of August, early September, it had finished blooming. The leaves take up a sleeping position at night. Common in all sandy bays in almost all tropical areas.

12. *Ipomaea insularis* Steud. [*I. indica* (Burm.)]. Though not common, it occurs scattered across the island, except the area around the lagoon. The hirsuteness of the leaves varies among the individual plants. Hillebrand: Very common in the lower vegetation of the Hawaiian Islands; occurs also on Tonga, Viti, Ladronen, Norfolk and on the coast of E. Australia.

13. *Nama sandwicensis* Gray. [N. s. var. *laysanicum* Brand.] This plant grows on the higher parts of the beach around the island. It is thickly covered with leaves; the specimens form very evenly developed dome-shaped rosettes (10 to 25 cm in diameter) which rise about 10 cm high above the sand.

14. *Heliotropium curassavicum* S. [*H. c.* L.] is restricted to the area of the lagoon which is not under water (see Nos 7. and 21.). There it forms a uniform cover of about 30 cm height. On this plant, as on Sesuvium, there are quite a few individuals of two small moth species, and so both plants are often visited by the three songbird species. Hillebrand: Common on the Hawaiian Islands on low, wet places near the sea. In America, from Oregon to Chile and from Mexico to Patagonia, also in Morocco and the Cape of Good Hope.

15. *Phyllostegia variabilis* Bitter nov. sp. Here and there on the E and W side near the beach. The numerous small flowers appear first during the winter, beginning in November.

It is a herbaceous plant, with few unbranched runners which I found to be 3/4 to 1 m long.

16. *Boerhaavia diffusa* L. is distributed everywhere on the island, especially between the singularly spaced tussocks of *Eragrostis*. This plant creeps low on the ground and rises but a few centimeters above it since its branches form quite a regular rosette out from the thick rootstock. The main root, which is sunk almost vertically into the ground, may reach a diameter of 15 cm, does not remain in real porportion with the quite scanty parts of the plant above the surface. The whole plant is sticky, one has difficulty cleaning off the adhering sand grains.

17. *Achyranthes splendens* Mart. *[A. s.* var. *reflexa* Hillebr.)] is restricted to an area of about 100 steps in diameter on the NW side, quite near the beach. This is a tightly compressed stand, not mixed with any other plants. Height 25 to 60 cm. It had already withered by August. According to Hillebrand, it also occurs on Maui and Lanai.

18. *Euxolus viridis* Moq. [*Amaranthus viridis* L.]. Solitarily growing at the brackish pond in the southern guano field, a few specimens also occur at the N end of the island near the lagoon among *Chenopodium*. Forb-like, 2 to 3 ft high. According to Hillebrand, accidentally introduced to the Hawaiian Islands; there, in much shorter growths than on Laysan.

19. *Chenopodium Sandwicheum* Moq. [*C. oahuense* (Meyen) Aellen] next to *Eragrostis*, is the commonest plant on the island. Mostly growing tightly beside one another, giving quite the characteristic appearance of a 3/4 m high, very thick shrub. Individuals which stand alone are dome-shaped, tightly leaved to the ground, and often several meters in diameter. It lost its leaves in the beginning of September in dry areas, where it looked completely dead. By the first half of the winter, all individuals had lost their leaves. Hillebrand: on all Hawaiian Islands, but most commonly occurring on the high plateau of Hawaii. It is but a few feet high near the coast, but Hillebrand found it to be 12 to 15 ft high in the higher situated forests of Mauna Kea .

20. *Santalum Freycinetianum* Gaud. [*S. cuneatum* var. *laysanicum* Rock.] occurs in the coastal zone of the island, most luxuriantly on the NW side. This bush is the tallest plant on the island since it may reach 2.5 m or more in height, whereas its main stem reaches 10 cm in diameter. The wood is very fragile. The fruit is the size of a small cherry, having a stone and a little flesh, which in the beginning, looks gray, and later, is colored bluish red. Almost all fruit is eaten by the birds. According to Hillebrand: in the forests of Maui, Lanai and Molokai, there growing to 12 to 25 ft height.

21. *Cyperus laevigatus* L. This plant forms thick, 60-7- cm high tussocks of great luxuriance, in large areas in the vicinity of the lagoon. Also, it occurs in a very deep area on the north side; the quite deep peat-like mass which one finds there is likely formed by this plant. According to Hillebrand, it is common near Honolulu in the proximity of brackish water. It is a common plant in many tropical tracts of the New and Old World.

22. *Cyperus canescens* Vald. [*C. pennatiformis* var. *bryanii* Kükenthal]. It occurs by itself, as well as mixed with *Eragrostis* and may, circumstances permitting, grow at least as high as the latter grass. Although widely distributed, it is by no means as common as this latter one, because it only thrives in moister places and does not occur at altitudes. Thus, it is restricted to the closer or wider surroundings of the lagoon. Hillebrand: In the lower regions of Oahu, Molokai and Maui: 1 to 3 ft high (thus considerably lower than on Laysan). It is spread from the Mascarenes and India through Malaysia, Australia, S. China to the Phillippines and to most Pacific islands.

23. *Cenchrus calyculatus* Cav. [*C. agrimonioides* var. *laysanensis* F. Br.]. This grass occurs as individual plants, 1/2 to 3/4 m high, among Eragrostis and only on dry sites.. It begins to flower at the end of December, most specimens have finished blooming already in July. Hillebrand: on dry sites between 1000-3000 ft elevation, likely occurring on all Hawaiian islands, although mainly in old lava fields of Maui and Hawaii. Elsewhere, also on the Society and Friendship islands, Pitcairn, Samoa, Viti and New Caledonia.

24. *Sporobolus virginicus* Kunth. [*S. v.* (L.) Kunth.]. It grows in very tight bunches at higher locations in the proximity of the seashore, especially on the N side. The stiff, peculiarly dry stalks may be 1/3 - 1/2 m long. It begins to bloom in August. Hillebrand: In certain places of the beaches of Oahu and Maui, otherwise in tropical and subtropical America, also in S. Africa and Australia.

25. *Eragrostis hawaiiensis* Hdb. [*E. variabilis* (Gaud.) Steud.] next to *Chenopodium*, is the most widely distributed plant on the island (see p.37). One to 1 3/4 m high. Mostly grows in single bunches, more rarely in tussocks. The main blooming period is October and November. According to Hillebrand, in Hawaii (Kohala), but there only 2-3 ft high.

26. *Lepturus repens* (Forst.) Occurrence is similar to that of No. 24, there quite common. It is a dry and hard grass which grows partly in clusters, and partly growing along the sand in several meter long, straight runners. It begins to flower only in August (whereas by then, the main blooming period of Nos. 22,23 & 25 are already over). It seems that only some specimens bloom, while most others remain sterile. Hillebrand does not list this grass among the Hawaiian flora; it grows elsewhere in Australia and in the surrounding Pacific islands.

Finally, we should remember the palms (see p.16), which Kittlitz already mentions (in 1834, in the Museum Senckenbergianum). In 1859, there were still 5 specimens on the island (according to Capt. Brooks); the tallest reaching 15 ft. I myself saw no more living specimens, although I found numerous stumps and pieces of root in the northern part of the island; some having a diameter of 50 cm. I also found numerous remnants in the southern part of the island, not far from the lagoon. Thus, the original numbers of trees were certainly several hundred. According to verbal information, the palms had hugh fan-shaped leaves

and long florescences and fruit racemes. In all likelyhood it was *Pritchardia.*

27. *Pritchardia Gaudechaudii* H. Wendl., [*Pritschardia* sp.] which occurs in natural conditions on the rocky cliffs of the northern coast of Molokai, singly in Hawaii and also on Bird Island.

It has already been pointed out on p.16 that, remarkably, many plants on Laysan show a rosette- or dome-shaped growth. I cannot give a definite reason for this fact. The wind conditions cannot be responsible for it. The only effect of the NE tradewind, the wind that predominates on Laysan, is that the vegetation on the E side is very much lower and poorer than on the protected W side.

It is a remarkable fact that the plants of Laysan seem to be considerably larger and more robust compared to specimens from the Hawaiian Islands.

I found most plants in bloom during my sojourn on the island (24.VI — 24. IX) ; the exceptions have been especially pointed out above.

Although the difference in seasons on Laysan is not significant and mainly manifests itself as a change in the winds, and in the different amounts of precipitation, some plants are still affected by it. Most of them certainly remain relatively unchanged the year around, although they look greenest in winter and spring, becoming faded and dry in high summer months (e.g. *Eragrostis*, *Sporobolus*, etc.). Others, to the contrary, are beginning to lose their leaves in September, especially *Chenopodium*, *Capparis* and *Scaevola*; the first two looking quite bald and dead all winter and, e.g. *Capparis* gets new leaves first in March. The salt plants near the lagoon (*Sesuvium* and *Heliotropium*) look quite black during the winter and first become green in the spring.

17) p.17. The following is a preliminary list of the birds of Laysan. I will shortly be giving a detailed account in the Journal für Ornithologie.

A. Specific for Laysan : *Acrocephalus familiaris* Rotsch. 2. *Himatione Freethii* Rotsch. 3. *Telespiza cantans* Wils. (*T. cantans* Wils. and *T. flavissima* Rotsch. are *one* species and therefore the latter must be cancelled). 4. *Porzanula Palmeri* Froh. 5. *Anas laysanensis* Rotsch.

B. Other breeding birds. *6. Fregatta aquila* Lin. 7. *Sula cyanops* Sundev. 8. *Sula piscatrix* L. 9. *Phaeton rubricauda* Bodd. 10. *Gygis alba* Sparrm. 11. *Haliplana lunata* Peale. 12. *H. fuliginosa* Gm. 13. *Anous stolidus* L. 14. *A. hawaiiensis* Rothsch. 15. *Puffinus nativitatis* Streets. 16. *P. cuneatus* Salv. 17. *Oestrelata hypoleuca* Salv. 18. *Bulweria bulweri* Jard. & Selby. 19. *Oceanodroma fuliginosa* Gm. 20. *Diomedea chinensis* Temm. 21. *D. immutabilis* Rothsch.

C. Regular visitors of the island (but not breeding there). 22. *Charadrius fulvus* Gm. 23. *Strepsiles interpres* L. 24. *Totanus incanus* Gm. 25. *Numenius tahitiensis* Gm. 26. *Sula sula* L.

D. Winter visitors . *27. Limosa novae* Zelandiae Gray. 28. *Calidris arenaria* L. 29. *Tringa acuminata* Swinh. 30. *Tringa* (*Pelidna*) *americana* Cass. 31. *Crymophilus fulicarius* L. 32. *Larus glaucescens* Brun. 33. *Phalacrocorax pelagicus* Pall. 34. *Anas boschas* L. 35. *Nettion crecca* B. 36. *Dafila acuta* L. 37. *Querquedula circia* L. 38. *Spatula clypeata* L. 39. *Clangula albeola* L. 40. *Diomedea* nov. spec. ? (close to *nigripes*).

The nest and eggs of *Himatione Freethii* were not known until now. I have found these and may briefly describe them as follows: since the selection of building material is very limited, the nests of the land birds of Laysan show a great similarity regarding their materials. The nest of Himatione Freethii consists predominantly of fine rootlets with only a few intervowen grass blades. Contrary to the nest of *Acrocephalus* which it almost resembles in size, it uses few or no feathers at all in its construction. It also differs from the latter in that its nest is more firmly fitted together and is not as deep. I found it mostly in the centre of high grass bunches, and also, sometimes in very thick *Chenopodium sandwichensis* shrubbery. In a clutch of 3 eggs, the only one I found, the basic color of two eggs was clear white, of the third with a tinge of light chamois. Next, there are numerous brownish-violet spots, but only on the blunt pole; these were, on two of the eggs, somewhat darker than on the third. Over these lay another set of larger or smaller, chocolate-colored spots and splashes. Although these are also mainly restricted to the area of the blunt pole, a few, smaller spots are also scattered over the remaining, pure white surface of the egg, and especially in the case of the third egg, with a yellowish tinge. It is typical that the blunt end appears as a lighter disk owing to the wreath-like arrangement of the spots around it. Length of two eggs was 20.5 mm, breath 14.5 mm; these measurements for the third egg were 19.75 and 14.0 mm.

18) p.28. My fish collection will be studied by Dr. Steindachner and published in the memoirs of the Academy of Vienna.

19) p.29. Of the insects I found on Laysan, only the following (excepting Diptera and Formicidae): Lepidoptera, Noctuidae (identified by Dr. Rebel): *Apamea chersotoides* Butl. and *Spaelotis crinigera* Butl.; the latter occurred in astonishingly hugh numbers. Its "grublike caterpillar" lives under ground on the roots of *Eragrostis*. Pyralidae: *Zinckenia recurvalis* F. Also a small, unidentifiable Tineidae. Hemiptera: *Nabis spec.* Hymenoptera: *Chelonus cameroni* D.T. (=*carinatus* Cam.) (Transact. Ent. Soc. 1881). Coleoptera: *Dermestes domesticus* Garm., occurring in unbelievable large masses. *Silvanus surinamensis* L., *Tribolium ferrugineum* F., *Clytus* is North American, the other three are cosmopolitan. Surely all four beetles must have been introduced only a short time ago.

Finally, there was a large, introduced *Periplaneta.*

The following are the spiders[12] of Laysan: *Theridion rufipes* Lucas., *Smeringopus elongatus* Vins., *Sapinatus melanognathus* Lucas. (These three species live in the hot belts of the whole world. *Lycosa stygialis* E. Simon (also on the Hawaiian Islands), *Melanophora pacifica* spec. nov. (belongs to a family which otherwise has a temperate palaearctic distribution; it is even related to *M. rustica* Koch, a European species, and it seems to stay near the only known species from Australia (*M. flavescens*). *Chelifer Laysanensis* spec. nov. (related to some species already known from Oceania).

20) p.31. The ants occurring on Laysan are, according to the identification of Prof. E. Emery, Bologna[13] 1. *Monomorium gracillimum* F. Sm., 2. *Tetramorium guinense* F., 3. *Tapinoma melanocephalum* F. (these three are cosmopolites). 4. *Ponera punctatissima* Boy subsp. *Schauinslandi.*

21) p.33. The climate of the island, corresponding to its position, excells through a relatively high, but also a very even temperature. During our stay (24. June — 24.. September), the minimum/maximum thermometer recorded the lowest temperature, 21°C (at night), and the highest, 37°C (in the shade). The coldest day of 1896/97 was 31st December with 17°—18°—17°C (6 am, 12 noon, 6 pm), while the 23rd February still showed 26°—29°-28°C. One of the highest temperatures observed on Laysan was on 7th October 1897, and was 41°C. The temperature, and other meteorological data, shall be prepared later. During the summer months, from May to early September the trade wind is not only the dominant, but almost the only wind. It blows mostly from the NE, but it may turn to N, or through E to S. In winter, contrarily, westerly and northerly winds predominate; they blow at times, quite violently, although real hurricanes were not observed. During my stay on the island, I was able to observe that almost all the time when calm prevailed, a heavy westerly swell pressed onto the island, this making passage through the western entry often impossible. Apparently, not far N of Laysan, the westerlies are dominant, and the swell they cause would be stopped by the E tradewind that predominates Laysan, but when the eastern trade is missing the swell is able to reach the island.

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[12] E. Simon: Arachnoideen aus dem Pacific. Zool.Jahrbücher, systhem. Abth. 12. Bd. 1899.
[13] Zoologische Jahrbücher, syst. Abth. vol.12.1899.

22) p.35. Of the catch up to now, the plankton algae were the first to be worked up.[14] The Crustaceans are being studied by Prof. G. O. Sars. Besides typical planktonic algae such as *Rhizosolnia*, *Ceratium tripos* Nitzsch., *Asterionella actata* Grun. etc., the plankton in the vicinity of Laysan also contained many bottom dwellers, which obviously were torn off by the heavy surf.

The plankton material which was collected during the journey from Laysan to Honolulu contained both warm and cold water forms. It is characterized by the numerous occurrences of *Rhizosolenia*, *Ceratocorys*, *Ornithocereus*, *Ceratium*, *Haliarachne lenticularis* Lemm. nov. gen. & spec. *Katagnymene pelagica* Lemm. & *spiroides* Lemm. nov. gen. & spec., and by mass occurrence of an normally sessile alga: *Enteromorpha flexuosa* (Wulf.) J. Ag.

[14] Lemmermann, Abh. Nat.Ver.Bremen 1899. Issue 2.

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ATOLL RESEARCH BULLETIN

NO. 433

HISTORY AND ORNITHOLOGICAL JOURNALS OF THE *TANAGER* EXPEDITION OF 1923 TO THE NORTHWESTERN HAWAIIAN ISLANDS, JOHNSTON AND WAKE ISLANDS

BY

STORRS L. OLSON

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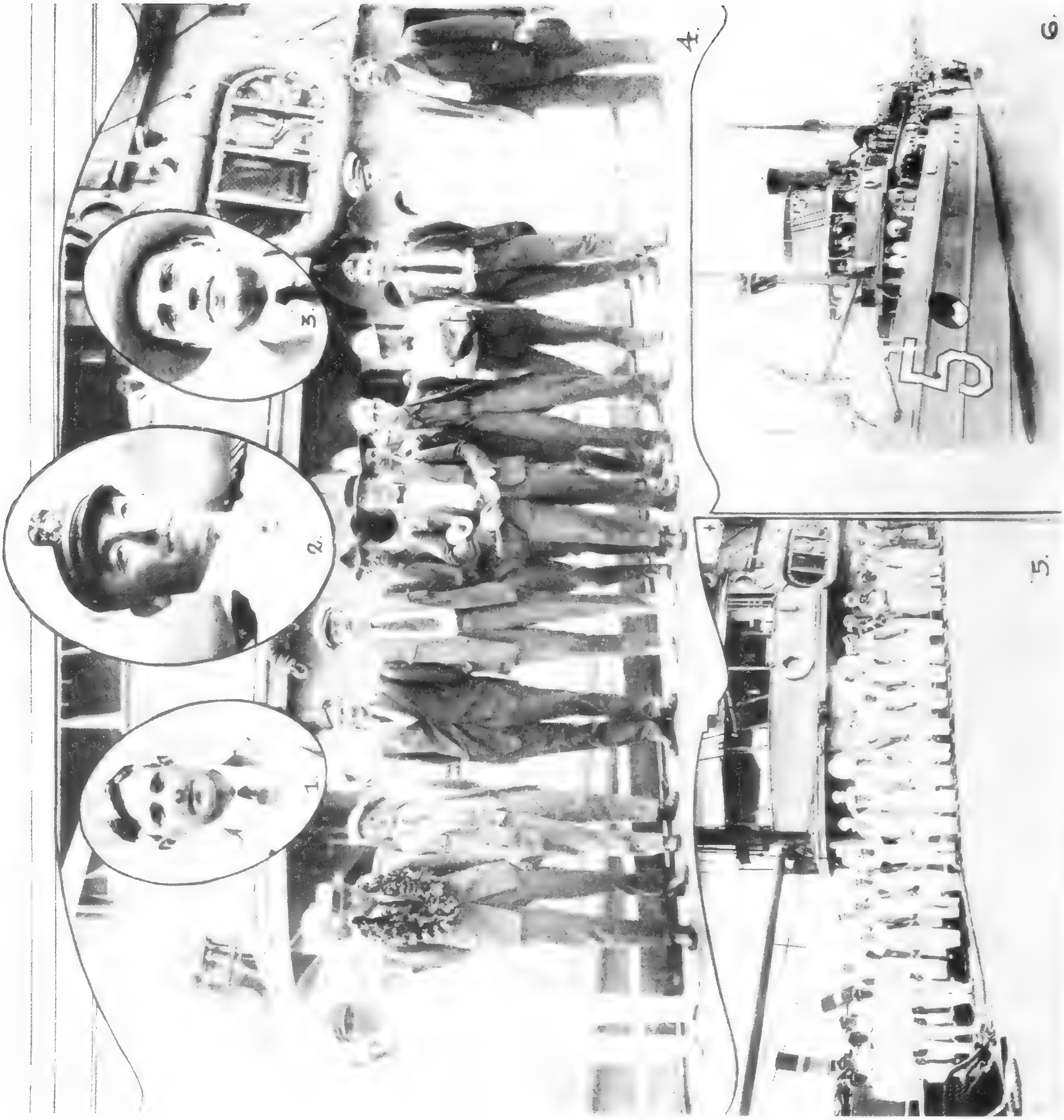

Figure 1. An official composite photograph of the TANAGER Expedition of 1923. Individuals were identified by Wetmore on another copy. The portraits above are (1) Alexander Wetmore, (2) Commander Samuel W. King, and (3) Hebert E. Gregory, Director of the Bishop Museum. The expedition members on the first leg of the expedition (4) are, left to right: King, A. J. Ker, C. Grant, Wetmore, D. R. Dickey, D. Fullaway, S. C. Ball, E. L. Caum, D. Thaanum, C. E. Reno, E. Schlemmer, T. Wilson, J. W. Thompson. The first five individuals in (5) were listed as King, Boatswain John D. Carroll (mate), Lt. Cdr. Wilson (ship's doctor), Heil (not further identified), and Stephen Ingham (the skipper).

HISTORY AND ORNITHOLOGICAL JOURNALS OF THE *TANAGER* EXPEDITION OF 1923 TO THE NORTHWESTERN HAWAIIAN ISLANDS, JOHNSTON AND WAKE ISLANDS

BY

Storrs L. Olson[1]

ABSTRACT

The TANAGER Expedition was mainly a natural history survey of the islands of the Northwestern Hawaiian chain, Johnston Atoll, and Wake Island that was undertaken jointly by the B. P. Bishop Museum and the Bureau of the Biological Survey in 1923, with assistance of the U. S. Navy. It was also important for conducting geographical surveys of those islands and even provided names for some of the smaller islets within atolls that are still in use. Although much useful scientific information emanated from the expedition, most of the ornithological results were never published. However, detailed journals were kept by the expedition's leader, Alexander Wetmore, and also by Donald R. Dickey, the expedition's photographer and only other ornithologist. These journals have been transcribed and annotated and are published here in their entirety, along with a brief history of the expedition compiled from archival sources.

INTRODUCTION

The TANAGER Expedition of 1923, so named for the naval vessel that provided the primary means of transportation for the endeavor, was a joint effort between the Bureau of the Biological Survey (U.S. Department of Agriculture), the Bernice P. Bishop Museum of Honolulu, and the United States Navy. The purposes of the expedition were several. In 1909, by decree of President Theodore Roosevelt, the far-flung Northwestern Hawaiian Islands (with the exception of Midway, which was administered by a cable company) were designated the Hawaiian Islands Bird Reservation, with their administration being the responsibility of the Biological Survey. The TANAGER Expedition was in part a fact-finding mission relative to the Survey's mandate as caretaker of the Bird Reservation. It was also known that rabbits introduced onto Laysan Island had caused serious ecological damage by eliminating vegetation, so it was a particular goal of the expedition to eliminate rabbits from Laysan. The primary objective of both the Biological Survey and the Bishop Museum, however, was a thorough biological reconnaissance of the islands, including documentation by adequate series of specimens of terrestrial and marine organisms. The expedition was not without benefit to the Navy as well, through gathering of navigational and other data of military use.

One of the expedition's principal architects was Herbert E. Gregory, Director of the Bishop Museum, who, however, did not take part in field work himself. The expedition's leader was Alexander Wetmore, then an Assistant Biologist of the Biological Survey, and one of the leading ornithologists of the 20th century. His boss at the time was Edward W. Nelson, Chief of the Biological Survey, a renowned mammalogist and ornithologist, and very much the chief in deed as well as name.

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To accompany transcriptions of the two ornithological journals kept on the voyage, I have compiled a brief history of the expedition, mainly from materials in the Smithsonian Institution Archives, where most of the TANAGER materials are located among the Wetmore papers (Cooper and Cox, 1990), in Box 141 (folders 6-8) and Box 142, with most photographic materials in Box 171 (album 2), Box 172, and Box 196 (folder 13); correspondence with H. E. Gregory is in Box 24 (folder 1); and post-expedition correspondence with Nelson is from Box 45 (folder 6). Numerous photographs illustrating vegetation and physiography of the islands have been published previously, and modern developments in cameras and color film would make publication of most photographs of birds from the expedition superfluous. Therefore, in selecting photographs I have attempted to use mainly those that show something of the people and camps of the TANAGER Expedition. Photographs are from Wetmore unless indicated otherwise, and the unbracketed portions of the legends for these figures are those written by Wetmore that appear in three albums among the archival material cited above.

Acknowledgments

The impetus to compile this history came from Thomas R. Howell, who had access to a copy of Dickey's journal and was keen to have it published. He supplied me with a type-written transcription from the original, which was scanned by computer at the Smithsonian by William Boykins, who also made photographic prints from Wetmore's negatives. I corrected the manuscript for scanning errors and the result was read back against the original journal by Howell. This version was also read by Donald R. Dickey, Jr. I transcribed Wetmore's journals directly from the originals into computer and then edited and annotated both journals. I am indebted to William Cox for much assistance with material from the Smithsonian Institution Archives. Robert Pyle kindly forwarded a copy of the holdings of the Bishop Museum Archives Department relative to the TANAGER Expedition. I thank Donald R. Dickey, Jr., and Katherine Donahue of the Louise Darling Biomedical Library, UCLA, for supplying the photographs taken by Dickey, Sr., on Laysan that I have included here. Roger B. Clapp called certain obscure references to attention. For information on specimens of marine mammals in the Smithsonian collections I am grateful to James Mead and Charles Potter, and for information from the bird collections to Phillip Angle and James Dean. I thank Patrice Belcher and Carla Kishinami of the British Museum for bibliographic assistance. Camera-ready copy was prepared by Taina Litwak

BRIEF HISTORY OF THE *TANAGER* EXPEDITION

General Background

It appears that the idea for the TANAGER Expedition, originally envisioned as covering only the Hawaiian islands of the Bird Reservation, came from Professor Herbert E. Gregory, a geologist from Yale University, who was then Director of the Bernice P. Bishop Museum in Honolulu. Gregory (1924) mentions plans developing from conferences in 1922 of the Committee on Pacific Investigations of the National Research Council, but it was probably more through Gregory's contacts in the islands that the support of the U. S. Navy was originally elicited. The Bishop Museum stood to add to its collections by sending personnel from various departments, but because the islands to be visited were under the administration of the Biological Survey, Gregory naturally had to secure the support and cooperation of the Survey's chief, E. W. Nelson.

Nelson saw the advantage to his Bureau of this arrangement and was agreeable, though the details of financing and itinerary remained to be worked out. Immediately, the two administrators assumed the usual feinting and dodging to be expected of them regarding funding. Nelson, like any good bureaucrat, was ever willing to poormouth his own potential resources and limitations, often with vigorous candor (*in litt.* to Gregory 4 August 1922)

> You mention the fact that the wages and subsistence of the Hawaiian members of the crew could probably not be met by payment from Navy funds and state that that will not be very serious as they could probably be obtained for three months' work for less than $2,000. I hope you know where the $2,000 are coming from. You are no doubt aware that the funds of the Biological Survey are appropriated for specific purposes and we will be put to it to carry our end of the work with some help from friends from the outside.

At the same time, he raised the possibility of extending the expedition to islands outside the Bird Reservation, but did not wish to pursue this further until arrangements for the expedition, as originally proposed, were solidly in line, although he hoped that

> When the boat is in commission and is conducting the work it might be feasible, at exceedingly small additional expense, to take in a few other islands. This is a matter for consideration when you are here [in October], and if you think it practicable we could take it up with Colonel Roosevelt [Assistant Secretary of the Navy].

On 1 February 1923, Henry C. Wallace, Secretary of the Department of Agriculture, wrote a formal request to Edwin Denby, Secretary of the Navy, requesting the Navy's participation in the expedition in order to obtain information desirable for his department, which included the Biological Survey, but which, according to the commandant at Pearl Harbor, would also "result in the accumulation of considerable information valuable for the use of the Navy." In this request he also suggested that it would be desirable to obtain information from "neighboring outlying islands . . . especially Midway, Wake and Johnston." Midway is mentioned not because it was "outlying" but because it was not part of the Bird Reservation.

Secretary Denby acquiesced in the original request to visit the Northwestern Hawaiian Islands but introduced a note of reality into the scientists' further expectations by pointing out that "a round trip to Wake Island will involve nearly 4,000 miles of steaming for a mine sweeper" and that the "schedule must be arranged with the Commandant." So much for Nelson's "exceedingly small additional expense." Even in 1923 the cost of the fuel alone for such a voyage cannot have been considered a trivial expediture. Nevertheless, the Acting Chief of Naval Operations on 8 February authorized the Commandant of the 14th Naval District to include Wake and Johnston islands in the expedition, and if need be to relieve the original minesweeper with another, adding that "the Department desires that the Commandant cooperate in every way possible with the party, and it is understood that Professor Gregory will be authorized by the Department of Agriculture to arrange all details." We must salute the foresight of those who thought to press for the inclusion of Johnston and Wake Islands in the itinerary of the TANAGER. The war in the Pacific that followed in less than two decades had a horrifying impact on almost all of the islands of that then-impacific ocean. Most of the relatively little that we know of the biology of Wake Island prior to this comes from the TANAGER Expedition.

On 10 February, Nelson confirmed by letter his previous arrangements with Donald R. Dickey that he accompany the expedition to Laysan as official photographer, in return for which he was to supply the Biological Survey with an edited copy of any motion

picture films, as well as duplicates of "such still pictures as may be desired by the Bureau to supplement those taken by its own representatives."

Nelson next sent official instructions (*in litt.* 12 February 1923) to Charles E. Reno, a Biological Assistant of the Survey in Phoenix, Arizona, who was to join the expedition as a pest control expert in order to eradicate the rabbits that were destroying the vegetation of Laysan. Nelson intended that Reno be well supplied for this task.

> We have arranged to have 75 ounces of strychnine sent to you directly at Phoenix for use on this trip. You will find it necessary to arrange in San Francisco for the purchase and transportation of from one to two tons of best grade bailed alfalfa for use in poison operations. In addition you will need to purchase at least two single shot 22 rifles and perhaps twelve thousand or fifteen thousand rounds of 22 caliber ammunition for use in killing rabbits. Other measures for the extermination of these animals will probably suggest themselves to you and can be arranged for.

The following day Nelson wrote again to Reno (*in litt.* 13 February) saying he would send along another 50 ounces of strychnine with Wetmore and authorizing Reno to purchase "four single shot .22 rifles and 15,000 rounds of short .22 calibre cartridges." He emphasized that:

> The destruction of rabbits on Laysan is a very important matter . . . . I hope you will be able to actually exterminate the last rabbit on the island during the month which can be devoted to that purpose. Failure to do so will be a great disappointment to me and would necessitate another effort at considerable expense.

Wetmore received his detailed instructions as expedition leader the same day (*in litt.* 13 February), among which was the remonstrance that:

> Independent individual arrangements should not be permitted since that would interfere with the unity of action and might result in friction and embarrassment. It is most desirable that everything should go on with the utmost harmony in order that the Navy might be pleased with the work and personnel and thus favorably disposed toward other possible similar expeditions.

On 14 February, the office of the Secretary of Agriculture approved the participation of the Biological Survey in the proposed expedition as well as authorizing the acceptance of $600.00 from the National Research Council towards the costs, and on 16 February specifically authorized both Wetmore and Reno to join the expedition, with "actual subsistence expenses not to exceed $5.00 per day" for each of them.

Wetmore's one-sentence "Permit to Collect Birds in the Hawaiian Islands Bird Reservation" was issued by Nelson himself on 20 February and sent from Jacksonville, Florida, where Nelson was at the time. In his letter of transmittal, Nelson hoped that the permit "may be of service to you in avoiding a surplus of volunteers when you get to Honolulu." I suppose this may have been because Wetmore was the only person named in the permit. Nelson also added that :

> I omitted to speak of the Warden of the Reservation who lives in Honolulu and who, if he desires to go to Laysan on the boat ought to be taken along in order that he may get a first-hand knowledge of existing conditions. The main usefulness for a warden stationed permanently at Honolulu, is in keeping track in a general way with what is taking place on the Reservation. It think it is worth the small salary we are allowing for the purpose.

The warden spoken of was Gerrit P. Wilder, and the salary was nothing if not small---$25.00 per month. Nelson also expressed concern that Wetmore take pains to determine whether any of the islands had been in use as a base for Japanese fishermen and to describe and photograph any structures that may have been erected on the islands, as "such occupation will be absolutely illegal and must be stopped." Wetmore was also instructed to take plenty of film to document the expedition with photographs, and also to make sketch maps of the islands, indicating any fresh water.

Cancelled Participation by the American Museum of Natural History

At one point it had been planned that the American Museum of Natural History in New York would be a joint participant in the expedition. Robert Cushman Murphy, renowned marine ornithologist at that museum, had written to Nelson regarding this prospect on 30 January 1923 (letter not seen) and arrangements may well have preceded this because by February of that year $1200 towards the expedition had already been received from L. C. Sanford, a wealthy benefactor of the AMNH and amateur ornithologist. Nelson then wrote to Murphy (*in litt.* 12 February 1923):

> Every effort will be made to fill your specific list of desiderata from the island as set forth in detail. As was understood in our conference in New York, the matter of securing specimens in addition to those listed as needed for the reserve series of the American Museum will depend on the time and ability of Dr. Wetmore and his assistants to secure and make up the material, in addition to getting specimens to meet the requirements of the Biological Survey series and the comparatively few needed to complete the representation of the species of the Bishop Museum. There appears to have been a misunderstanding on your part as to the division of the specimens which might be obtained by Dr. Wetmore in case he had opportunity to visit some of the principal islands after the bird expedition is completed. I informed Dr. Sanford that if Dr. Wetmore got sufficient material some would be added to the specified list, but I did not intend to convey the idea that the results of this side-trip of Dr. Wetmore's, which is rather in the way of a personal venture on his part, would be divided half and half.
>
> We figure that the cost of the entire expedition covering the salaries and expenses of Dr. Wetmore and his two assistants to and from the United States will amount to a total of something more than $6,000, of which Dr. Sanford's contribution amounts to about one-fifth.
>
> I trust that while there Dr. Wetmore will be able to secure enough immature young and eggs of the species so that a portion of them can be allotted to the American Museum. Every effort will be made to provide a thoroughly good return for the $1,200 contributed. The National Research Council has placed in my hands its contribution of $600 to help defray the expenses.

In a letter to Sanford written the same day Nelson (*in litt.* 12 February 1923) elaborated further.

> Wetmore and I have figured out the cost of the expedition including salaries and expenses and find that it will somewhat exceed $6,000. This is considerably more than we expected to begin with and will crowd us to take care of, but we desire to do the work in a satisfactory way and to have assistants enough to secure the desired series of bird skins.
>
> While your contribution covers about one fifth of the total expenditure, it is a very important element in covering the cost of the work. I appreciate the fact that the call for this contribution came at an embarrassing time and that you met the call at some personal inconvenience. I trust that the results may be so satisfactory that you will be pleased at having participated.

Nelson's formal letter of instructions to Wetmore issued the following day (13 February 1923) contained the following paragraph:

> You have a copy of Dr. Murphy's letter from the American Museum specifying the list of birds desired for their collection through Doctor Sanford's contribution to the expenses of assistants. You will make every effort to first secure as nearly as possible the full list of the specimens desired for the study series of the American Museum as set forth in Doctor Murphy's letter. In addition, so far as opportunity provides, you should secure specimens to complete the further requirements of Dr. Murphy's list.

Only five days later, in a very brief memorandum dictated by Nelson and signed in his absence (*in litt.* to Wetmore 18 February 1923), Nelson aborted the whole plan:

> In thinking over the matter of the contribution from Dr. Sanford to the Hawaiian expedition I have decided that in view of the willingness which he repeatedly expressed to me to have his participation canceled it will be best for you to draw your check for the $1200 and inclose it in a letter which I am sending Sanford. The letter will be prepared and will be sent as soon as your check is ready to inclose.

A handwritten note attached to this memo reads:

> Dr. Wetmore; I found this in my safe deposit box & am returning it to its author.---E.W.N.

In Wetmore's hand is added:

> (This money was not used, but was returned to Sanford.) A.W. Dr. Sanford wanted me to take an extra man to prepare a set of skins for him. I found however that $1200 would not cover the expense so Dr. Nelson cancelled the arrangement. The money was returned to Sanford.

On 20 February Nelson wrote to Wetmore from Florida:

> I trust that the Sanford matter has been satisfactorily adjusted so that you will be relieved of that part of the detail thus leaving you free to devote yourself more exclusively to the purposes of the Bureau. I anticipate a superb lot of specimens and other results.

It is pretty obvious what went on here. As long as Sanford was willing to provide money in exchange for some quantity of specimens to be selected by the Biological Survey, all was fine. When the prospect changed to one of Sanford sending his own collector along who might potentially compete for specimens, and over whom the Bureau might be unable to exercise complete control, Nelson and Wetmore dropped the whole proposition like a hot rock. The sum of $1200 would have been quite sufficient to cover the expenses of an additional person whose transportation between Honolulu and the mainland had also been covered, but I suspect that Nelson was not about to share any portion of the scientific spoils of the expedition on other than his own terms.

The impression of suspicion and rivalry between Washington and New York is further strengthened by the communications regarding Frank R. Lawrence joining the expedition (see Wetmore journal for May 15th and 29th). Nelson (*in litt.* to Wetmore 26 June 1923) seemed particularly exercised over this matter.

> Your confidential letter of June 9 from Honolulu, concerning the addition of Mr. Lawrence, of the Bishop Museum, to your party, has been received. I trust you will be very certain that he makes no collections which will go to the American Museum, and if it proves that he is a representative of the American Museum and his photographs go to them for their use, I shall consider that it is a very unpleasant case.

> Furthermore, any publication by the American Museum of an account of the bird reservation obtained on the present trip without first securing the permission of the Secretary of Agriculture, through this Bureau, would be absolutely unjustifiable and would look like a case of taking an unscrupulous advantage, particularly in view of the fact that their subscription to the trip was withdrawn. Naturally the publications concerning this expedition should be prepared by you, with any additional matter to come through our consent. We certainly do not need his assistance in preparing reports on the expedition.
>
> From what you write concerning the large number of people on the expedition it appears to me that the Bishop Museum must be taking advantage of the opportunity to the full extent at least. The question is whether the opportunity is not being crowded, particularly if men like the man representing Murphy, which appears not to be a scientist but merely a writer. I should consider additions of that kind to the party beyond the subject of our agreement and of a kind which was not contemplated when Doctor Gregory and I had our conference. Of course, it will be desirable to avoid any controversy unless forced into it, but I certainly should include in any other expedition a definite understanding to cover cases of that kind.

Any controversy in this and other matters was evidently avoided because Wetmore subsequently received numerous commendations for his efficient and tactful leadership of what proved to be a harmonious expedition.

Wetmore's Instructions for Collecting

With regard to collecting, Nelson had very specific ideas that he laid out in detail in his letter of instructions to Wetmore (13 February).

> You should make a special effort to get two or three representatives at least of the immature plumages of each of the species breeding on the islands and also three or four sets of eggs of each, where it is practicable.
>
> In connection with the collecting on the islands I desire to call your attention to the need of carefully supervising the taking of the rare land species peculiar to each island which may exist there in so small a number as to[o] large a collection of these birds might endanger them. That is a matter for your judgment to determine. Where these peculiar species of land birds exist in sufficient numbers I would like to have for our collection a good working series. In the matter of the Laysan Teal, the number which you should take will depend upon the number on the island. It has been reported that thirty or forty of them were seen there at one time not long since. Another report gives the number as two individuals. Should the former report be true and any considerable number exist, you should take a generous number of them for the collections, owing to the danger of these birds being exterminated, but be sure to leave enough so that there will be reasonable certainty the birds will have opportunity to reproduce next spring and thus renew the number.
>
> Apparently Wake Island is of considerable size and the bird fauna is but little known. While there you should make a special effort to get a good substantial series of everything not occurring on Laysan, from albatrosses to any land birds. Any land birds occurring there are probably peculiar to the island and special effort should be made to get a series of them. It will be well to make a special search here for the Pacific seal which is likely to occur. These seals are also found occasionally on Laysan and whenever you have opportunity you should not fail to get specimens of them. Should you be able to do so you ought to secure at least ten specimens. They are so rare and live in such a remote region that they are almost unknown in scientific collections. Efforts should be made to secure adult specimens with one or two of the small young to represent that stage of development. Should the species not be represented in the Bishop Museum and you secure enough so that an adult could be spared for them you could turn one over to Professor Gregory.

> As has been decided in conference you should salt and send in flat skins of all of the larger birds only making up the peculiar small land species and possibly a few of the smaller sea birds. Owing to the difficulty of getting to and from the ship on these islands it will greatly facilitate the work to have the birds prepared in this way and will also save the time of you and your assistants in the field and not necessitate carrying a great amount of field supply such as cotton and other material. No attempt should be made to thoroughly clean the fat from the skins before they are salted, merely roughing off any flesh and gobs of fat so to save as much time as it practicable. Your experience in the field will be a sufficient guide as to this.

Of the last part of this plan, Wetmore did not approve, as he once told me directly and as is revealed in his letter of 26 November 1934 to E. H. Bryan, quoted below. He had doubtless expressed his disapproval of salting skins in this manner prior to receiving his instructions, which may explain why Nelson went to such pains to spell out the exact procedure to be followed. Nelson was definitely the chief and he got his way. His reasons were perfectly valid in many regards, although at the other end, back in the museum, many years were to elapse before all these specimens could be properly prepared as study skins for examination.

Collections of other than birds and mammals were to be made by, or for, the Bishop Museum, with the Survey to "have no definite claim on" them "beyond what is turned over to us voluntarily by the museum." Tentative plans were made for Wetmore to do some exploration and collecting in the main islands at the end of the expedition, as alluded to in Nelson's correspondence with Murphey, but this never materialized because of problems with permits.

In responding to letters from Wetmore of 21 March and 1 April, Nelson expressed pleasure that Wetmore had "secured eight seals and a good series of birds . . . . I hope that you may have found Laysan teal sufficiently numerous to get a handsome series of them, and that you may discover a new species of teal on Wake Island besides other new things" (*in litt.* 23 May).

Nelson, in acknowledging a wire from Wetmore concerning Lisianski and a letter of 30 April, indulged in more "micromanaging" of the field collecting (*in litt.* 24 May).

> You do not mention having taken any specimens of Laysan Teal, but that seventeen were seen. I trust you will not fail to get a reasonable percentage of these birds, since, as they are left to themselves, they can readily breed back. I hope also that you secured at least one nest and set of eggs. It is extremely interesting that you have found the seals so numerous on some of the islands visited and have been able to get photographs and learn something of their habits. This information will of course all be new and will enable you to prepare a most valuable contribution to the life history of these practically unknown animals. I hope that you may get some unknown species on your visit to Wake and some of the other islands. Owing to the extreme rarity of specimens of the seal in museums, I wish you would not fail to get a total of anywhere from fifteen to twenty specimens, of which the larger part should be full-grown males and females. It may be many years before there will be such an opportunity as you are now having to get these animals, and it appears to me a pity not to take advantage of it to get a goodly numbers. In addition to getting the skins and skulls of fifteen or twenty of the animals it would be a good thing if you could get at least a couple of complete skeletons of an old male and an old female.
>
> I do not wish to burden you personally with work in this matter, but I take for granted that you are able to get the assistance of sailors or others to prepare specimens of this character, you merely directing how the work shall be done.

To emphasize his desire for additional specimens of seal, Nelson cabled the following message to Wetmore on the same date (24 May): "Important you get if practicable fifteen to twenty seals nearly all fully adult and a good skeleton of each sex."

Wetmore had at that time already prepared 8 skins and skulls of seals (including one for the Bishop Museum) and one complete skeleton, as well as collecting 9 skulls of individuals that had died previously. He had by then already left Lisianski, the last island where the expedition encountered seals, which was probably a relief, as he can hardly have relished the prospect of the labor involved in preparing and packing another 8 to 13 individuals.

Again concerning the teal, Nelson wrote (*in litt.* 26 June):

> I hope you may run across either the Laysan teal or an unknown representative of it on Wake Island, where you can get a nice series. In view of the fact that the birds were about to breed the time you were on Laysan and the other adverse conditions, I think you were right in limiting the number of specimens you took.

Critics in the age of the Endangered Species Act who may consider that Wetmore acted irresponsibly for collecting six specimens of Laysan Teal when the population totalled only 20, should bear in mind that he was under direct orders from his superior, the ultimate keeper of the the Hawaiian Bird Reservation, to obtain a good series, and that Wetmore had to justify taking so few as six. In any case, Nelson was correct that the population would "breed back," as once the rabbits had been eliminated, the numbers of ducks increased to over 500 by the 1950's (Warner, 1963).

Publication History of the of the *Tanager* Expedition

Wetmore and Bishop Museum director Herbert Gregory had made detailed plans for publication of the results of the TANAGER Expedition (Fig. 4.), which were to appear in the *Bulletin of the Bernice P. Bishop Museum.*

Wetmore, however, published almost nothing of substance, his only scientific contribution from his Pacific voyage being a two-page note describing the expedition's single new taxon of bird, the Nihoa Millerbird (Wetmore, 1924). This was most uncharacteristic because Wetmore was a prolific writer who usually brought out the results of his field work promptly and completely. His failure to publish in this instance stemmed partly from rapid career changes with greatly increased responsibilities. Shortly after the TANAGER Expedition, Wetmore left the Biological Survey to become Director of the National Zoological Park in November 1924, a position that he quickly vacated on 1 April 1925 to assume the post of Assistant Secretary of the Smithsonian Institution. He held this position until 1945 when he became Secretary, from which he retired in 1952.

On 4 April 1925, only three days after Wetmore had assumed the post of Assistant Secretary of the Smithsonian, Gregory wrote to him as follows:

> Two of the manuscripts of the Tanager Expedition, "Marine invertebrates" and "Fishes," go to press this month. Botany, insects, land shells, and archaeology are about ready. How about seals, rats, lizards, and birds assigned to Alexander Wetmore? Now that I have the money, I'd like to publish all the stuff this year.

> Was that gentleman also going to supply a general account of the doings of the Expedition? I hope so, for apparently it is up to me to write whatever I can't get from you, for King appears to have his mind on his new jobs and Atkinson, Cartwright, Wilder, and some others seem to have only faint recollections of any responsibilities assumed.

The lizards were identified by Leonhard Stejneger at the Smithsonian, who declined to attempt to dignify his efforts as a paper, saying that the species involved were widespread in Oceania and that there was nothing to be said about them beyond a list of species with their islands of occurrence, which he supplied (Stejneger *in litt.* to Gregory, 5 June 1925). Commander King, who had left the Navy prior to 15 June 1925 (Wetmore *in litt.* to Gregory), was supposed to supply material for an itinerary, of which Gregory was still optimistic as late as 18 July 1925 (*in litt.* to Wetmore). But neither King nor Wetmore supplied this want, so that the brief overview that Gregory wrote in his annual report (Gregory, 1924) had to suffice.

PUBLICATIONS - TANAGER EXPEDITION

To be issued as Bulletins
with secondary title,
"Tanager Expedition, 1923.
Publication No. "

SUBJECT	CONTRIBUTORS	RESPONSIBLE AUTHORS
History, Narrative, Description, etc.	To be prepared by Wetmore cf. letter Gregory, April 1925. King Atkinson All the Staff	Gregory
Birds	Wetmore	Wetmore
Fish	?	Ball
Land Shells	Cooke	Cooke
Plants	Caum Wilder Pollock	Brown
Archaeology	?	Judd
Geology	All Staff	Palmer
Mammals	?	Wetmore
Lizards	?	"
Insects	Fullaway Bryan Others	Bryan
Land fauna	?	Edmondson
Marine fauna	Crant-Thaanum	Edmondson

Popular

Figure 2. Wetmore's copy of a flow chart outlining plans for publication of the results of the TANAGER Expedition.

Gregory must have been instrumental in insuring that the Bishop Museum lived up to its obligations concerning publication, as the museum issued 8 papers in its *Bulletin* and *Occasional Papers* covering most of the subjects for which its staff was responsible, with the exception of mollusks (Table 1).

Table 1. TANAGER Expedition publications in the *Bulletin of the B. P. Bishop Museum.*

TANAGER Expedition Publication No.	Subject	Reference
1	Marine Invertebrates	Edmondson, et al., 1925
2	Ichthyology	Fowler and Ball, 1925
3	Entomology	Bryan et al., 1926
4	Geology	Palmer, 1927
5	Archaeology	Emory, 1928
6	Botany	Christophersen, 1931
7	Botany	Christophersen and Caum, 1931
None	Entomology (Mallophaga)	Thompson, 1948

Wetmore did eventually publish an abbreviated popular account of the expedition that was abstracted from a larger, more-informative manuscript (copy in SI Archives). He had a little added incentive and perhaps a nagging sense of obligation to complete this, as we learn from Gregory (*in litt.* to Wetmore 28 January 1924).

> Our mutual fried, Major Chapman Grant of the Tanager, has a writing habit which may develop into a disease requiring treatment. I have taken no notice of his interviews with Hawaiian papers, and have given permission to the New York Aquarium journal to publish a two page account of Wake Island. Now comes from the Associate Editor of The National Geographic Magazine a 6000 page [sic] manuscript (with many photographs) on the "Leeward Islands' Bird Reservation" with a statement that the article is submitted for publication provided the Director of the Bishop Museum does not block its route. I am delaying my reply until I have your view.

However long Grant's manuscript may actually have been, Gregory had it suppressed, with the recommendation that such an article ought to be written by Wetmore. The result was Wetmore's second and final publication dealing with the TANAGER Expedition that appeared in the *National Geographic Magazine* (Wetmore, 1925). Another popular article appeared considerably later using TANAGER Expedition photographs from the Bishop Museum (Gill, 1930).

I had once suspected that ill feelings may have contributed either to Wetmore's abrupt departure from the Survey or to his subsequent neglect of his Hawaiian work, as I was aware that he disagreed with Nelson on the matter of how bird specimens should be prepared in the field. This was not the case, however. Wetmore assumed the zoo directorship because it practically doubled his salary and because it gave him a greater degree of autonomy than he could have had at the Survey. His correspondence with Nelson then, and for years afterwards, though formal, was quite cordial. In explaining his departure to Nelson, who was then in Arizona, Wetmore optimistically forecast that "the report on the Hawaiian work I can write as soon as Barrett completes the salted skins from the collection" (*in litt.* 8 November 1924). Therein lay a primary cause of delay.

A full decade later, he wrote (*in litt.* 26 November 1934) in response to an inquiry from E. H. Bryan of the Bishop Museum, his former companion on the TANAGER:

> My own report on the birds of the Tanager expedition has been unfortunate but I am still hoping to do something with it. When I started out on this expedition I wanted to make up the specimens in the field but Dr. Nelson, my chief, would not listen to this plan as he said that they all should be salted so perforce I followed his orders. On my return there were so many of the salted skins that the taxidermists were a number of years in getting them all cleaned up. In fact, it is only about three or four years ago that the last were finished. In the meantime I have come into other responsibilities and while I am writing steadily my researches are necessarily somewhat curtailed, and lead into other channels. For the past four or five weeks for example I have been busy for most of my spare time in giving opinions to others on the use of names and similar points. I have held the Hawaiian material segregated and really intend to write a report upon it.

But perhaps by then it seemed stale or was of less interest than current projects and the report was never written. Except for Wake, all of the islands visited by the TANAGER were investigated again in detail during the Smithsonian Institution's Pacific Ocean Biological Survey Program (POBSP) in the 1960's and 70's, which resulted in a series of comprehensive reports (Table 2).

Table 2. Monographs concerning islands visited by the TANAGER expedition published in *Atoll Research Bulletin* .

Island	Reference	Bulletin #
Nihoa Island	Clapp, Kridler, and Fleet, 1977	*ARB* 207
Necker Island	Clapp and Kridler, 1977	*ARB* 206
French Frigate Shoals	Amerson, 1971	*ARB* 150
Gardner Pinnacles	Clapp, 1972	*ARB* 163
Laysan Island	Ely and Clapp, 1973	*ARB* 171
Lisianski Island	Clapp, and Wirtz, 1975	*ARB* 186
Pearl and Hermes Reef	Amerson, Clapp, and Wirtz, 1974	*ARB* 174
Kure Atoll	Woodward, 1972	*ARB* 164
Johnston Island	Amerson and Shelton, 1976	*ARB* 192

These authors had access to Wetmore's unpublished journal and notes, to which they referred repeatedly, but what they extracted was mainly data on population sizes and reproductive cycle, so that much other information contained in these sources remained unpublished and inaccessible to the scientific public. Three additional reports in *Atoll Research Bulletin* dealt with the biota of Wake Island (Bryan, 1959; Fosberg, 1959; Fosberg and Sachet, 1969), but not nearly as comprehensively as in the preceding monographs, and these authors did not consult Wetmore's journals, so that his accounts of Wake Island become especially valuable.

Wetmore's journals are important for more than their biological content, because the TANAGER Expedition was itself a significant event in the history and geography of Hawaii and the Pacific. For example, the expedition in general, and Wetmore in particular, was responsible for naming many of the islets of Pearl and Hermes Reef, French Frigate Shoals, and Wake Island---names that are still in use today.

The expedition also took place at a time when several of the endemic species of birds of the islands were facing imminent extinction. The Laysan Millerbird (*Acrocephalus familiaris*) had probably become extinct only months before the arrival of the TANAGER, and the last individuals of the Laysan Apapane (*Himatione sanguinea freethii*) disappeared during a sandstorm practically under the eyes of a party of the TANAGER expedition camped on the island. Only 20 individuals of the Laysan Duck (*Anas laysanensis*) remained and the Laysan Rail (*Porzana palmeri*) had nearly disappeared from Laysan but still persisted on Midway, where it had been introduced. Wetmore made practically the only scientific observations of the Wake Island flightless rail (*Gallirallus wakensis*) prior to its extinction during the Japanese occupation of that island---observations that have never been published in their entirety.

Other archival material from the expedition exists in addition to Wetmore's journal. That at the Bishop Museum I have not examined except for an inventory of the archives and an itinerary of the expedition prepared by someone other than Wetmore. An important source augmenting Wetmore's documents is the journal of Donald R. Dickey, the only other ornithologist on the expedition. Much of Dickey's journal, which relates only to Laysan, covers a period when Wetmore was on islands to the west, so that there is relatively little overlap in content in the two journals.

The Minesweeper TANAGER and Her Commander S. B. King

The history of the ship TANAGER, as summarized from Mooney (1981), is a noble one, quite apart from her contribution to natural history and geography during the 1923 expedition. TANAGER was a minesweeper displacing 840 tons, with a length of 188 feet and 35 foot beam. Her keel was laid 28 September 1917 by the Staten Island Ship Building Company, New York, the ship was launched 2 March 1918, and commissioned 28 June 1918.

In World War I, TANAGER saw service in the North Sea, where twice she was damaged sufficiently severely, once by heavy weather and once by a mine, to require repairs in port. She was assigned to the Pacific Fleet in December 1919 and operated out of Pearl Harbor from 1920 to 1941, when she received a major overhaul. At the outbreak of the Pacific war with Japan, TANAGER was one of few ships to escape from the Japanese attack on Cavite Navy Yard in the Philippines on 10 December 1941, after which she operated out of Corregidor on inshore patrol duties. "In ensuing months, Tanager and her dwindling number of sister ships and former China river gunboats lived a furtive, hunted existence," until 4 May 1942 when she was hit by Japanese shore batteries on Bataan and sank off Corregidor later the same day, which also marked the beginning of the Battle of the Coral Sea.

Commander Samuel Wilder King (1896-1959) was the admiral's representative aboard the TANAGER for the duration of the expedition. He would have been 27 years of age at the time. Wetmore, who was ten years King's senior, had the highest regard for him and commemorated King's name in that of the only new bird discovered on the expedition, the Nihoa Millerbird. Notes accompanying the list of TANAGER holdings in the Bishop Museum archives remark that King "is of special interest to the people of Hawai'i, as he later became Governor of the Territory of Hawai'i, governing from 1953 to 1957. King was elected as a representative to the Hawai'i State Legislature in 1958 and was planning to run for the State's first governorship when he died on March 24, 1959."

He was also a delegate to Congress from 1934 to 1942, and a school in Kaneohe, Oahu, is named for him (Pukui et al., 1974).

Figure 3. Samuel W. King, Commander of the TANAGER Expedition, later to play an important role in Hawaiian politics and whose name lives on in the scientific name of the Nihoa Millerbird, *Acrocephalus kingi*. Photograph by Donald R. Dickey.

Itinerary and Scientific Personnel

The following is a modified version of an itinerary prepared by Wetmore after the expedition, a copy of which is in the TANAGER archives at the Smithsonian. Wetmore also listed the personnel for each leg of the expedition in his journal. I have deleted these lists from the journal but have incorporated any additional information in them in parentheses in the present itinerary. I have also used a different itinerary in the Bishop Museum archives, as well as that supplied by Gregory (1924) to make corrections in Wetmore's version, as well as for supplementary information, such as given names. Apart from adding this additional information, I have kept as closely as possible to the finished itinerary prepared by Wetmore, including the order in which names are given. Boldface entries indicate the initiation of Wetmore's main period of activity on a given island.

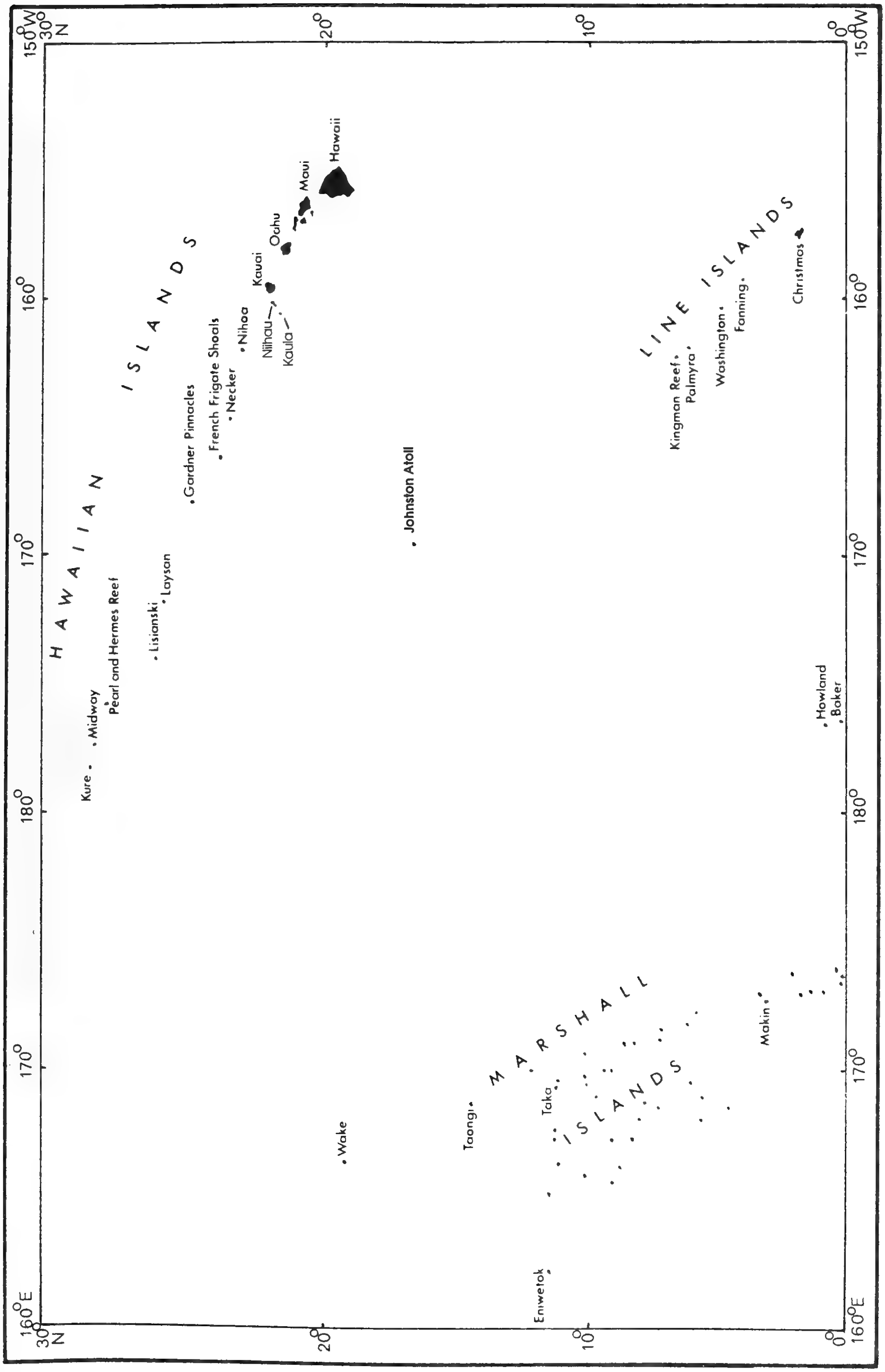

Figure 4. Map of the central Pacific Ocean showing islands visited by the TANAGER Expedition. Modified from Amerson and Shelton (1976).

There was a second TANAGER Expedition in 1924, headed by H. S. Palmer, that went only to Nihoa and Necker, mainly to extend the archeological investigations begun in 1923 (Gregory, 1925), but that is not included here.

ITINERARY OF *TANAGER* EXPEDITION, 1923

April 4. Left Honolulu at noon.
    Lt.-Comdr. Samuel Wilder King, Representative of Admiral.
    Chief boatswain Stephen Ingham, Commanding Officer of TANAGER.
        Personnel of Scientific Party.
            Alexander Wetmore, in charge.
            Charles E. Reno, specialist in rodent control [often given incorrectly as "E. C. Reno", as in Gregory (1924), Dickey's journal, etc.]
            Donald Ryder Dickey, photographer, motion and still pictures
            Dr. Stanley C. Ball, biologist.
            David Thaanum, conchologist (collector of marine invertebrates).
            David T. Fullaway, entomologist (Board of Agriculture).
            Edward L. Caum, botanist.
            Chapman Grant, assistant (my assistant in ornithology, army major in detached service).
            Eric Schlemmer, assistant (general utility man, son of Max Schlemmer) [erroneously as "Max Schlemner, Jr." in Gregory (1924)].
            J. W. Thompson, preparator (expert in fishes Bishop Museum).
April 7. Arrived **Laysan Island**.
April 8. Established shore camp and began operations.
April 14. With part of party TANAGER continued west.
        Personnel of western party.
            A. Wetmore, in charge.
            D. F. Fullaway.
            E. L. Caum.
            D. Thaanum.
            C. Grant.
            Rest of party with George Higgs, Navy cook, in camp on Laysan.
April 15. Anchored in late afternoon at Midway.
April 16. Continued to **Ocean Island**, where King and Wetmore reconnoitered passage through reef.
April 17. Shore camp established.
April 22. Broke camp and transferred to **Midway** where quarters were obtained at Cable Station, through kindness of Superintendent M. E. Desnouée.
April 23. Visited Eastern Island.
April 25. Left Midway at daybreak and arrived at two p.m. at **Pearl and Hermes Reef**.
April 26. Landed on Southeast Island.
April 27. Landed on Grass and Seal islands.
April 28. Landed on Southeast Island.
April 29. Arrived at **Laysan** 2:00 p.m.
April 30. TANAGER departed at 6:00 p.m. for Honolulu, taking Dickey, Thompson, Caum, and Fullaway, with remainder of party in camp on Laysan.
May 13. TANAGER returned in evening and sent boat ashore following morning.
        Additional members of scientific party.
            Gerrit P. Wilder, warden of reservation and botanist (Federal warden for the Hawaiian Bird Reservation. To inspect the islands and to replace Caum as botanist.)

Lorrin A. Thurston, conchologist (owner of Honolulu *Advertiser*--conchologist to assist in collecting shells.)
Austin Jones, fisherman (friend of Dr. [Talmadge] Wilson on the TANAGER come for the fishing.)
Theodore Dranga, conchologist and expert diver.
Frank R. Lawrence, photographer (according to a letter from Gregory "A wealthy New Yorker--amateur naturalist and expert photographer. He is sent at the request of the American Museum with the hope that his interest may be aroused to the point of financing some project. He has agreed to be a general slave." A friend of Murphy.)
John Baker, fisherman (native Hawaiian fisherman to assist in collecting fishes. Was supposed to make the first trip but missed the boat.)

May 14. Broke camp on Laysan.
May 15. Landed camping party on **Lisianski** with following: Wetmore, Schlemmer, Ball, Thaanum, Grant, Baker (with G. Higgs, Navy cook). The TANAGER conveyed Reno with Wilder, Thurston, Dranga and Lawrence to Pearl and Hermes Reef where Reno exterminated a rabbit colony on Southeast Island.
May 19. TANAGER returned to Lisianski.
May 20. Broke camp and started east.
May 21. Anchored off **Gardiner Island**.
May 22. Landed Wetmore, Schlemmer, Thaanum, Ball, Wilder, Dranga, Baker and Dr. Wilson (of the TANAGER) on Gardiner, where a party remained until noon. Left Gardiner at 9:00 p.m.
May 24. Arrived at Nihoa in afternoon where we remained at anchor until morning of
May 26. Unable to land because of contrary winds.
May 27. Arrived Honolulu 6:00 p.m.
June 9. TANAGER sailed at five with following in party:
A. Wetmore, in charge.
E. Schlemmer.
C. S. Judd, ethnologist (Forester and Executive officer of Board of Agriculture. To assist in ethnological work.)
Bruce Cartwright, ethnologist (President Hawaiian Historical Society).
E. L. Caum, botanist.
D. Thaanum, conchologist.
Dr. C. Montague Cooke, conchologist (interested primarily in land shells).
Dr. Harold S. Palmer, geologist (Prof. of Geology, Univ. of Hawaii).
Edwin H. Bryan, entomologist (Bishop Museum).
C. Grant, assistant (to collect fishes and marine life).
A. L. C. Atkinson, assistant (lawyer interested in heiaus on Necker)
Arthur H. Rice, assistant (President Board of Agriculture out for the trip) [Gregory (1924) and the Bishop Museum itinerary has Atkinson as President of the Hawaiian Board of Agriculture and Forestry, and Rice as a "collector of fish."]
W. G. Anderson, assistant (general assistant. Sailor and fisherman, acquainted to a certain degree with Nihoa.)
June 10. Landed following party on **Nihoa** in evening, Wetmore, Schlemmer, Cooke, Thaanum, Bryan, Grant, Geo. Higgs, Navy cook.
June 11. TANAGER transferred other members of party under leadership of Judd to Necker.
June 16. TANAGER returned having left Atkinson and Anderson on Necker. Transferred Nihoa party to ship and landed Judd, Palmer, Cartwright, Caum, and a Filipino cook on Nihoa. At 2:00 p.m. TANAGER left for Necker.

June 17. Landed party on **Necker** at 8:00 a.m. and arranged camp. At 4:00 p.m. the TANAGER left for Waimea taking Cooke, Atkinson, Rice, and Anderson.
June 20. TANAGER picked up party at Nihoa.
June 21 TANAGER arrived 6:30 and camp was broken. Anderson returned to join party.
June 22. Arrived **French Frigates Shoal** and established camp on East Island.
June 24. In late afternoon transferred camp to Tern Island. During work here all of the islands in the lagoon except Disappearing Island were visited by motor-sailer. On June 27 we worked around the base of La Perouse Rock.)
June 26. Left French Frigates Shoal.
June 29. Party landed on Necker for day while TANAGER made soundings in vicinity.
July 1. Circumnavigated **Kaula Island** in small boat, unable to land because of adverse wind. Arrived Honolulu 11:15 p.m.
July 7. Left Honolulu on Mine Sweeper WHIPPOORWILL with destroyers BURNS and LUDLOW in attendance, with Captain Torrant in command. A hydroplane aboard WHIPPOORWILL .

Personnel of scientific party:

A Wetmore, in charge.
E. Schlemmer, assistant.
C. H. Edmondson, biologist.
E. H. Bryan, entomologist.
James B. Pollock, botanist.
C. Grant, assistant.
W. G. Anderson, assistant.
Geo. Higgs, Navy cook.

[July 10. Arrived **Johnston Island** and established camp.---This date and event inadvertently omitted from the original.]
July 12. Destroyers left for Honolulu leaving WHIPPOORWILL behind.
July 19. U. S. S. TANAGER arrived. Ships spent most of day transferring oil. Additional members of scientific party D. Thaanum, conchologist, H. S. Palmer, geologist, J. B. Mann, topographer, and Orme Cheatham, assistant (a young man to serve as assistant to Pollock and to make himself generally useful). WHIPPOORWILL returned to Honolulu.
July 20. Left Johnston Island on TANAGER.
July 27. Established camp on **Wake Island**.
August 5. Broke camp and embarked.
August 13. Arrived Honolulu.

THE ORNITHOLOGICAL JOURNALS OF THE *TANAGER* EXPEDITION

Throughout his life Alexander Wetmore was a dedicated chronicler of his field activities. He jotted information first in pocket notebooks and later transcribed more detailed information into 5 x 8 inch looseleaf notebooks. In the field he maintained at least three sets of notes---his field journal, which was a record of daily activities, general natural history observations, and not a little about birds as well; a field catalog of specimens collected; and species accounts in which each species of bird observed received a separate page until a page was filled and another started. He would eventually have his field journals and catalogs neatly bound. The entire massive set of documents is maintained in the Division of Birds, National Museum of Natural History, Smithsonian Institution.

Wetmore's handwriting is somewhat cramped and spare, without loops or adornment. To the uninitiated it can be difficult to decipher and is sometimes rather like what I would imagine it must be like to read Hebrew, in which there are no vowels. In Wetmore's case the vowels are present but often indistinguishable one from another save that "i"s are usually dotted (although not necessarily over the letter to which the dot properly belongs). Wetmore also had the convenient habit of underlining the letter "u" so it would not be mistaken for an "n", although this little dash often becomes rather confusingly incorporated into the line below. When one learns Wetmore's cadence, phraseology, and preferred vocabulary, one has few problems, and many otherwise totally indecipherable words are easily made out from their context. Occasionally, however, as when some foreign word is introduced, the spelling may be all but impossible to determine.

Figure 5. Donald R. Dickey on Laysan Island, 1923. From the Dickey collection at UCLA.

Dickey's journal is a less formal, more personal document. Donald Ryder Dickey (31 March 1887 -- 15 April 1932) was an enthusiastic naturalist of independent means,

an amateur in the positive connotation of that word, who specialized in ornithology and mammalogy and had a particular interest in both still and motion photography (Wood, 1932; Harris, 1934). He lived in California from 1910 until his death and assembled an important collection of over 50,000 specimens of vertebrates, now housed at the University of California at Los Angeles (UCLA). He is best known for his work on systematics of birds of El Salvador, with his curator Adriaan van Rossem, which culminated in a posthumous monograph on the avifauna of that country (Dickey and van Rossem, 1938)

It was Dickey's skill as a photographer that earned him a place on the TANAGER Expedition, which he joined only for that portion of the trip devoted to Laysan Island. His journal is important because it covers the period when Wetmore was away on other islands. Dickey was present during the infamous sand storm that was the final cause of extinction of one of the Laysan endemics, the "honey eater" *Himatione sanguinea freethii*. Dickey's insightful observations into the probable causes of diminution in numbers of that species and those of other land birds prior to this event are particularly worthy of attention, and the vigorous style of his journal will be appreciated as well.

In expressing his shock at Dickey's death nine years after the TANAGER Expedition, Wetmore wrote (*in litt* to Nelson, 25 April 1932): "I counted Dickey as one of my closest friends, and feel his loss very keenly. . . . He is one of the finest men I have known, a statement that I make after having been closely associated with him in the field under circumstances that at times were somewhat trying. As you well know there is no truer method of arriving at a man's real worth than this."

Having written many field journals myself, I am well aware of the errors that habitually are committed due to necessities of haste, poor light, and other less than ideal conditions met with in the field. Such notes are seldom reread and corrected by their original authors. In transcribing Wetmore's field notes, and to a lesser extent Dickey's, I have made some changes as follows. I have automatically made minor corrections in spelling, word duplication, and word omission, without resorting to the use of masses of brackets, "sic"s, and other distractions when it is perfectly obvious what was intended. Strikethroughs (which are relatively numerous) are not indicated except in a few special instances when they may reveal something not otherwise apparent. I have introduced additional punctuation to promote clarity, and I have adopted a few other conventions, Wetmore's use of uppercase letters and underlining being inconsistent at best. I have tried to render English names of birds and all scientific names (italicized) in a uniform manner but have maintained the usage that was current when the journals were written (for modern equivalents and other synonyms consult the list provided below). I have spelled out "male" and "female" rather than using sex symbols, and have spelled out numerous abbreviations, especially those that might be confusing, such as Dickey using "m." for mile. In a few cases when the same statement is made twice nearly verbatin I have eliminated the redundant part. Numerous short paragraphs have been combined as larger ones. Very occasionally I have moved portions around so that the sequence of discussion is more logical. Those parts of the journals not devoted to the actual days of the TANAGER Expedition itself I have condensed except where they bear on the objectives and logistics of the expedition. From Dickey's journal I have omitted several data sheets giving technical details of film exposures and also his field catalog, which was written in at the end of each day on which specimens were collected. The information noted there is largely repeated in his journal. He listed 48 specimens, which are presumably at UCLA. I have also added headings to facilitate finding an account of a particular island. All material in brackets [ ] and all footnotes are attributable to me.

List of Current Names of Birds and Synonyms as Used in the Journals

Many of the English and scientific names of birds as used in the Wetmore and Dickey journals are now obsolete. Below I have listed the currently accepted nomenclature, based mainly on American Ornithologists' Union (1983), with the various synonyms used in the journals following in parentheses.

Diomedea nigripes Black-footed Albatross (goony, gooney, Black-footed Gooney)
Diomedea immutabilis Laysan Albatross (goony, gooney)
Fulmarus glacialis Northern Fulmar
Pterodroma neglecta Kermadec Petrel (*Aestrelata*)
Pterodroma hypoleuca Bonin Petrel (*Aestrelata hypoleuca,* Bonin Island Petrel, white-breasted petrel)
Bulweria bulwerii Bulwer's Petrel
Puffinus pacificus Wedge-tailed Shearwater (*Puffinus cuneatus*)
Puffinus nativitatus Christmas Shearwater (Christmas Island Shearwater)
Oceanodroma tristrami Sooty Storm-petrel (Tristram's Petrel)
Phaethon lepturus White-tailed Tropicbird
Phaethon rubricauda Red-tailed Tropicbird (*Phaëton rubricaudus*--- all unspecified references to the genus or "tropicbird" refer to this species)
Fregata minor Great Frigatebird (frigate, frigatebird, man-of-war bird, man 'o-war)
Sula dactylatra Masked Booby (*Sula cyanops*, Blue-faced Booby)
Sula leucogaster Brown Booby (*Sula leucogastra*, Common Booby)
Sula sula Red-footed Booby (*Sula piscator*)
Anas laysanensis Laysan Duck (Laysan Teal, teal)
Gallirallus wakensis Wake Island Rail (*Hypotaenidia wakensis*, rail)
Porzana palmeri Laysan Rail (*Porzanula*)
Pluvialis fulva Asiatic Golden Plover (*Pluvialis dominica fulva*, plover, Golden Plover, Pacific Golden Plover---it is only recently that this taxon has been shown to be specifically distinct from the American Golden Plover *P. dominica.*)
Heteroscelus incanus Wandering Tattler (*Heteractitis*, tattler)
Numenius tahitiensis Bristle-thighed Curlew (curlew)
Arenaria interpres Ruddy Turnstone (turnstone)
Calidris alba Sanderling (*Crocethia alba*)
Sterna lunata Gray-backed Tern (graybacks)
Sterna fuscata Sooty Tern (Sooty-backed Tern, black-backs)
Anous stolidus Brown Noddy (*Anous s. pileatus*, Common Noddy---all references to *Anous* and most or all to "noddy" pertain to this species).
Anous minutus Black Noddy (*Megalopterus hawaiiensis*, *Micranous*, Hawaiian Tern, Hawaiian Noddy, small noddies)
Procelsterna cerulea Blue-gray Noddy (*Procelsterna saxatilis*, Necker Island Tern)
Gygis alba White Tern (Love Tern, Love Bird, Fairy Tern, *G. a. kittlitzi*)
Acrocephalus kingi Nihoa Millerbird (millerbird, *Tatare*, *Conopoderas kingi*. The Nihoa Millerbird *A. kingi* is treated by some authors as a subspecies of the extinct Laysan Millerbird *A. familiaris*, the genera *Tatare* and *Conopoderas* having been subsumed in the widespread Old World genus *Acrocephalus*).
Serinus canaria Common Canary (canary)
Telespiza cantans Laysan Finch (*Telespyza*, finch, canary)
Telespiza ultima Nihoa Finch (*Telespyza*, finch)
Himatione sanguinea Apapane (*Himatione freethii* or *fraithii*, Laysan Honeyeater, honeyeater)

THE JOURNAL OF ALEXANDER WETMORE

Washington to Honolulu

[Wetmore left Washington by train on 10 March 1923 at 6:40 p.m., arrived at Kansas City at 8:15 a.m. on 12 March and made a brief side trip to his alma mater at Lawrence, Kansas, whence he departed 11:52 a.m. on 13 March.]

March 14, Wednesday

Arrived in Denver at 7:15 a.m. in a blizzard which continued with a steady downfall of snow until noon. Bob Rockwell, good scout, met me at the station and we had breakfast together and talked until nearly nine. Went then to the Railroad Building to see Piper and remained for over an hour.

Piper estimated that 10 bales of good bright alfalfa would be more than sufficient for the work planned on Laysan. This may be dampened slightly with a very thin solution of starch and Karo [corn syrup] and mixed one ounce strychnine to 30 pounds of hay or dry strychnine may be mixed through hay. Cut carrots and beets would make good fresh vegetable baits. Steam-crushed oats also a good bait to try. Coarse shredded cornmeal mixed dry with salt and strychnine a good bait. If windy make into paste. Deposit in little scattered heaps of a tablespoon each. Also valuable to spray food plants with a tin starch mucilage containing strychnine, by means of a spray pump. Garlough has found powdered calcium cyanide injected in burrows by means of a knapsack blower useful on rabbits. [F. E. Garlough was an animal control expert who would himself later become involved in rodent control in the Hawaiian Islands and Wake Island in 1935-1937 (U. S. National Archives, Record Group 22, Entry 182)]. Piper has shipped me a package of processed strychnine that he wishes me to try as an experiment to determine its value against straight strychnine on rabbits. The brownish mixture contains blood, the plain white lacks the blood. These poisons are those manufactured for use of our rodent men.

Rockwell then drove me out to the Colorado Museum where I saw A. M. Bailey Bailey gave me a chart showing location of colonies of Tristram's and Bulwer's Petrels on Laysan. Petrels may be obtained by use of jack light at night. He said that there is a colony of [Hawaiian Monk Seal] *Monachus schauinslandi* on Pearl and Hermes reefs. He said that the sand island shown on the charts in the eastern part of this group apparently had disappeared but that seals were found on a smaller island to the westward, northwest of the anchorage. Bailey and Willet put Laysan Rails on Lisiansky in March, 1913. He said that on one occasion he killed 265 rabbits in an hour in a distance of 100 yards and recommended the use of .22 longs as they were tough and hard to kill. Also met Bob Niedrach again. Left Denver via U. P. at 1:30 p. m. [Alfred M. Bailey was ornithologist at the Denver Museum of Natural History for many years. He was a member of a University of Iowa expedition to the Northwestern Hawaiian Islands in 1912 and long afterwards visited Midway in 1946. A decade later he published a booklet on the birds of Laysan and Midway (Bailey, 1956).]

[15-16 March in transit and on the latter . . .]

Arrived San Francisco at 10:30 a.m. C. E. Reno came to the Wiltshire where I registered at 1:30 and we checked up our passage with the Matson Navigation Co. and arranged for shipment of supplies.

17 March, Saturday

Ordered ammunition, camp equipment etc. from Ellery Arms Co., 583 Market St., this a.m. and made miscellaneous purchases. [Went to Berkeley and met with various naturalists].

March 18, Sunday

[Went to Pacific Grove and met with W. K. Fisher, his wife, and the wife of A.K. Fisher and toured the coast to the south.] Dr. Fisher gave me valuable information on conditions at Laysan Island as he found them, as well as on Necker. The landing on Necker is on the north side. Left Pacific Grove at 6:15 and reached San Francisco at 10:30. [Albert K. Fisher (1856-1948) was a founder of the American Ornithologists' Union and long-time employee of the Biological Survey. Walter K. Fisher was his son and participated in an expedition to the Northwestern Hawaiian Islands in 1902 (Fisher, 1906).]

March 19, Monday

[Made arrangements for camp supplies and visited the California Academy of Sciences.] At four I returned to town and made out purchase orders for camp supplies and baled alfalfa. Alfalfa was double-compressed so that it occupies only one half the bulk of ordinary baled alfalfa. This will facilitate handling in small boats. [Dinner with Reno's sister and her husband.]

March 20, Tuesday

[More purchases, visiting, examined bird specimens at Berkeley.]

March 21, Wednesday

[Departed at noon on S. S. MATSONIA with Reno.]

March 22-26

[In transit, at sea.]

March 27, Tuesday

[Arrived at Honolulu and was met by Mr. Stanley C. Ball, Curator of Collections of the Bishop Museum, and checked into the Blaisdell Hotel.] At a quarter of twelve we accompanied Mr. Herbert E. Gregory to luncheon at the University Club where we met Mr. Gerrit P. Wilder, member of the territorial legislature, and Commander Samuel King. Commander King has been appointed by Admiral Simpson to have personal directive of the minesweeper on the western trip. Plans made for the expedition were discussed and approved. The boat will make four trips of a month each, three of them to the west islands and one to Johnston and Wake. [Went to the Bishop Museum with Gregory, to Waikiki for a swim, then dinner with the Gregorys.]

March 28, Wednesday

[Occupied with travel logistics, met with David T. Fullaway, territorial entomologist, and later with Mr. C. S. Judd of the Division of Forestry and discussed introduction of birds to the Hawaiian Islands and a collecting permit for the main islands. Met again with King and went to the Bishop Museum with Judd.]

March 29, Thursday

[Went to used book stores, met again with King, and went again to the Bishop Museum. The following passage, though not about the expedition, is included because of its potential historical interest.] At 1:50 Mr. Judd came for me and I attended a meeting of the board of Commissioners of Agriculture, Messrs. Atkinson, Rice and von Holt and talked before them on introduction of birds and bird protection. Recommended *Holoquiscalus* [West Indian grackles, Icteridae] and *Machetornis rixosa* [the Cattle Tyrant, a widespread South American flycatcher] as desirable birds to import. At present the board controls the importation of birds, for which there is considerable demand and pressure brought to bear. It has tentatively approved the introduction of:

1. Straw-necked Ibis *Carphibis* [*Threskiornis*] *spinicollis*
2. Peewee Lark *Grallina picata* [Magpie Lark *G. cyanoleuca*]
3. [Western] Meadowlark *Sturnella neglecta*
4. Shepherd's Companion *Rhipidura tricolor* [Willie Wagtail *R. leucophrys*].

[With the exception of the <u>Sturnella</u>, these are Australian species, which, if they were ever introduced, did not thrive. Meadowlarks were successfully introduced to Kauai in 1931.]

In the fall of 1922 six *Grallina picata* were secured from Josephs, the animal dealer, and liberated on the Parker Ranch on the Island of Hawaii. I recommended the *Carphibis* be dropped as it might prove destructive to frogs which have been introduced. Suggested further investigation of *Grallina* and gave the others a clear slate. Birds are desired that will feed in the open and destroy the armyworm and cutworm, which are injurious to grasses. The abundance and occurrence of these creatures is dependent on rains. They normally appear in May but may come earlier under favorable circumstances. The Golden Plover is thought to be an enemy of them. *Acridotheres tristis* [Common Mynah] is considered beneficial now.

March 30, Friday

Was occupied with various arrangements this morning. At noon the men who are to do the scientific work of the expedition met at lunch at the University Club to discuss plans. Eighteen were present. Dr. H. E. Gregory outlined the history of the expedition, Lt. Commander Samuel King described the boat and plans made for equipment and I spoke concerning the scientific work. Worked on birds at the Bishop Museum in afternoon.

March 31, Saturday

[Met D. R. Dickey when he arrived on CITY OF LOS ANGELES, worked at Bishop Museum, dined with Dickey.]

April 1, Sunday

[Rainy day, attended to expense accounts and correspondence].

April 2, Monday

Purchased needed articles of equipment this morning, two oil stoves (2 burner) for camp use, two lanterns, a hammer, nails, a small saw, empty boxes for packing specimens, cornmeal, salt, and other needed supplies. Was on board the minesweeper TANAGER at one and looked the boat over. Discussed plans for the trip with Dr. Gregory in the late afternoon.

In the evening Reno and I called on Max Schlemmer who resided on Laysan from 1894 until about 1907 or 1910. He was engaged there as foreman of the crew who gathered guano. He told me that he kept a diary and that the books were on file with the guano company at their offices. The guano deposits were finally exhausted and the island was abandoned. He described the guano as from one to three feet thick and as containing eggs, of which he had two *Sula* eggs and many bones. He said that in digging in the island he had encountered old deposits of bones at a depth of three feet. On one occasion he put down a well 18 feet deep and found bones at that depth. A few of the albatross arrive about October 25 each year. Others assemble a few at a time during the succeeding days until by the middle of November all are present. By June the young are mature and all forsake the island save a few cripples that soon die. During his early years, from 50-60 Laysan Teal were found on the lagoons. He never molested them. Other ducks among them "Canvas back" and "little black divers" came in winter and once he killed two Canada Geese and gave the heads to Bryan [presumably William Alanson Bryan of the Bishop Museum]. Rabbits were brought in about 1901. At that time, as old photos indicate, the island was pleasantly green with vegetation but now the rabbits have destroyed all this growth. He also brought in guinea pigs and had hogs there at one time but killed them as they destroyed too many eggs. Cows were brought over but died in a short time. Albatross were formerly more abundant than now. Schlemmer claims to own Laysan and Johnston Islands. He was taken out in 1916 by the THETIS and expected to establish himself as warden over the island but four months later was removed as a German spy.

April 3, Tuesday

[More purchases and errands, met with King and Admiral Simpson. In evening went to a hula with Reno.]

April 4, Wednesday

Embarked our baggage at eight this morning. Every one has a tremendous amount of duffel. Many were down at the dock to see us off including a flock of news photographers so that we were shot from every angle. The party was supposed to consist of eleven but at the last minute Grant [sic = John Baker, see 15 May], a Hawaiian fisherman, failed to show up and we left without him. [Personnel list omitted---see itinerary.]

Met Mr. Hines of the insular senate who complained bitterly of damage by goats on the island of Hawaii. Claimed that the goats overran government land. At the last minute [Lorrin A.] Thurston an influential man, owner of the *Honolulu Advertiser*, tried to put a man on board, a shell collector named Dranga. I gathered that Thurston had a private

collection and that he wished material for it. I consulted Gregory in the matter and found that he had refused to take the man as a member of his part of the party so turned the matter down. Thurston argued it for a considerable time.

We left at twelve and passed out through the harbor over gentle swell and went to the westward south of Oahu in the lee of the island. The day was clear and the sea calm. Toward dusk Oahu disappeared and Kauai came in sight. We passed between Niihau and Kauai and stood away for the north side of Nihoa. Black-footed Albatross were about in small numbers and I saw a few Wedge-tailed Shearwaters. A small forward deck in front of the pilothouse has been set aside for the scientists where we have a mess table and can spread our beds. Dr. Ball and I are to mess in the officer's mess below. The food is very good. A small compartment below is fitted with cots for our use but as the boat is small it is too close and stuffy for me save in emergency.

April 5, Thursday

The wind freshened during the night so that it was rough. The boat pitches and rolls heavily at slight provocation. At ten this morning we passed Nihoa. The sharp pointed peak was so high that it became visible at a distance of 30 miles and was in sight astern for an equal space. The Laysan Albatross appeared here. Many Black-footed Albatross are about the wake and hundreds of Wedge-tailed Shearwaters beat over the water. Occasionally we see a tropicbird (Red-tailed), *Sula cyanops*, a White Tern, or *Procelsterna saxatilis*, *Sterna lunata*, or a frigatebird. We passed Necker Island at midnight.

April 6, Friday

At eight this morning we were close in on French Frigate Shoals which displayed a hungry line of white breakers with a line of low sand islands lying behind their protecting fringe. A single rock marked higher land. A half hour delay here for repairs in the engine room gave time to look about. Bird life was abundant and I saw Red-footed Boobies. The Laysan Albatross is now fairly common but does not follow the wake as does *D. nigripes*. The shoals were soon behind as we stood on westward.

Laysan Island (Outward)

April 7, Saturday

At ten this morning we came in sight of the breakers of reef seen first at a distance of ten miles. While looking idly over the side my eye caught a pinnacle head as large around as a man's body that projected within four to six feet of the surface. I had noted a brown discoloration in the water at one side ahead but had thought that it would prove to be a shark, turtle, or porpoise and was astonished to find it a submerged rock lying four to six feet below the surface. A sounding gave a depth of 18 fathoms, revealing a platform extending beyond the reef to the southeast farther than supposed. We circled on our course in an endeavor to get a better look at the rock but failed to find it again, not a surprising thing considering the space of sea. We continued slowly over the shelf, sounding regularly and proceeding at half speed until south of the reef when we stood away direct for Laysan. Birds were now abundant. Laysan Albatross were seen on every hand. 12 to 15 [*Diomedea*] *nigripes* were constantly over our wake.

At five p.m. we sighted the two coconut trees on Laysan directly ahead and a little later came in toward the south. Shortly after six we arrived at the anchorage on the west side of the island. It was with mingled feelings that I swept Laysan with my glasses. As we lay a half mile away it presented merely a barren sand island rising a few feet above the water. Two coconut trees that rose in front of a half a dozen low tumbledown buildings with a low bush or two at either side were the only signs of vegetation. Birds were everywhere but there was no sight of green. Grave fears for the smaller birds passed through my mind and it seemed inevitable that the teal, millerbird, rail, *Himatione* and finch had perished.

Laysan Albatross pass continually. Frigatebirds soared over eyeing us curiously with hosts of four species of terns, and two of shearwaters passing on all hands. The ship rolled in the groundswell all night and I was awake at intervals disturbed both by the strange night noises and by plans for our camp ashore.

April 8, Sunday

Awoke this morning at six with a long slow swell rocking the ship. Enthusiastic fishermen among the sailors landed more sharks during the night at intervals, among whoops and yells of their companions, which, with a certain amount of planning and wondering about conditions on shore, interfered somewhat with restful slumber. Terns screamed and called all night and at daybreak a band of frigatebirds swung overhead and then circled high into the rising light of the sun.

A self-bailing surfboat was put over the side, luggage and food came up out of the hold, and at eight, with Commander King, Dr. Ball and Reno and a little personal equipment, I started ashore. The boat rode easily over the rolling swells and we came in with no difficulty through the opening in the reef into a tiny basin with little waves washing slowly and lazily up on a sloping beach of sand.

As we disembarked we had a clear view of the half dozen shacks that remain from the old guano station, now a in state of disrepair without windows or doors and in some cases with the roofs fallen in. Sand had drifted in among them partly filling the porch on the larger one and drifting in great heaps had half filled several rooms. Two coconut trees in front had in some strange way weathered the brunt of the encroaching sand and stood free, though more or less bent and scarred. Birds were everywhere; four or five Laysan Albatross stood on the sand of the porch with a fuzzy youngster half grown at the corner. Hawaiian Noddies rested on the roofs and window ledges, flying out with great clatter, while the White Terns rested on scant nests of *Sesuvium* stems, probably made by other birds, or perched about on the rafters or window sills inside. Wedge-tailed Shearwaters were everywhere, alone or in couples. The desolation of the scene with its appeal of the active bird life will remain long in memory. Birds were everywhere and, true to my imagining, were unbelievably tame. A Red-tailed Tropicbird bent on a nest under a porch chattered at us savagely---a protest joined by a group of Red-footed Boobies in the two or three stunted trees nearby. For half an hour I could do nothing but sit on the sand and enjoy and marvel at what my eyes beheld.

Another boat came off shortly with supplies, and work of organizing a camp claimed attention. A building with three rooms was chosen for workrooms and supplies, and a level flat just beyond made suitable place for tents. My own was in place in half an hour, though it was new and I had to stop to rig the guy ropes. By now most of our material had come off, including great stores of food and miscellaneous collecting gear was

strewn about. Tents were in place and the place assumed the orderly disorder of a permanent camp.

Seals, *Monachus schauinslandi,* were seen at two points near camp, two pairs, hauled out on the sand. Eric Schlemmer told me that usually when the island had been deserted for a time that seals were found at these points but that as soon as men appeared they left. I cautioned the men to keep away and awaited anxiously the arrival of my heavy rifle and the ammunition for it. The latter, purchased in San Francisco might be in one of several boxes, and only after some opening and search did I discover it. Slipping half a dozen shells into the magazine I hastened out to find a pair of seals hauled out on the beach three hundred yards from camp. The animals lay asleep just about the water's edge in the sloping sand lying prone with eyes closed. A shot thought the neck back of the head finished the first one without a struggle, though blood spurted out the two holes made by the thirty-eight fifty-five bullet for nearly five minutes. At the report the second animal barely stirred and a second shot, also in the neck, finished it without a quiver. It required the united effort of five of us to drag the largest above the high water mark. We left the two lying and returned for lunch. At two, Grant, Thompson and I returned and put up a tent fly above the animals and proceeded to skin them. To our surprise the largest animal was a female and the smaller one a male. Both were fully adult. The female was not pregnant. She was distinctly darker in color than the male. The tongue was fleshy and was distinctly bifid at the tip. The stomach of the female contained remains of twenty-five of the ordinary reef fishes from five to ten inches long. The intestine was highly convoluted. The animals were only moderately fat. We brought the two skins into camp and salted them in the evening after completing the flensing. Secured two taeneids and many nematodes from the one female.

Cool tonight so that I slept under two blankets and a quilt. I lay for a moment listening to the strange clamor of the birds before I dropped off.

April 9, Monday

This morning Grant and I, with Mr. [A. J.] Ker, a cable operator bound for Midway who was on board the TANAGER, went out and cleaned up the skeleton of the female seal, work that required until ten. On my return I found Commander King on shore and discussed various details with him. We prepared a message to Dr. Gregory recommending that work on the second voyage be devoted to the outer islands of Lisianski and French Frigate Shoals, leaving Necker and Nihoa for the third trip. Also wirelessed the office that camp established Laysan April eight. Island nearly bare of vegetation. Have two seals. Following this King, Reno, Dickey and I walked out across the island around the lagoon. Low areas here that are probably flooded after rains were covered with a mat of *Sesuvium*, a pigweed-like plant that was making a brave struggle against the depredations of the rabbits. The latter hopped or squatted about among the albatross and shearwaters, occasionally taking alarm and dashing away to run down a hole. Reno shot several, with the 22 long bullets striking them with a hollow plunk. About 150 to 200 have been killed here since our arrival. All are of large "Belgian Hare" size and vary in color. Grizzled grays and grayish browns predominate, with numbers of reddish brown, dull blacks and blackish brown. All had the abdomen well distended but two or three that were examined were not at all fat though in good flesh. I noted scattered carcasses of animals that had died before our arrival. The food supply here I take it is practically at a minimum for them. The *Sesuvium* in damp localities near the lagoon can spread its root system and produce a few leaves in spite of the attack of the mammals, while the number of the latter is held down by the food that the plant can supply. All rabbits seen were adult but Reno

found embryos in several females. Their number is without question fixed by the rate of growth of the plant.

I was greatly pleased to find eleven Laysan Teal here and numbers of finches. Laysan Albatross, Black-footed Albatross, Wedge-tailed Shearwaters and a few Blue-faced Boobies were scattered over the flats. Sooty and Gray-backed Terns were colonizing and frigatebirds soared overhead. Flocks of turnstone fed at the edge of the lagoon and I noted many Bristle-thighed Curlew and a few Golden Plover. I killed four Laysan Albatross on the return. Shot them through the base of the neck with a .22. The afternoon was occupied in demonstrating methods in skinning to Grant and Reno. Grant is to be my assistant for the first month at least.

Sailors from the ship have shovelled out part of the sand in the house now, the stewards have the shack they use for a kitchen cleaned out and camp is in good shape. Commander King sent off a mess table, benches and the table equipment that we used aboard ship so that we have china, silver, glasses and even a linen table cloth. Water from some of the new water breakers tastes strongly of the oak staves and some of the men are complaining about this and the fact that there is no fresh bread. Don't believe these lacks will permanently injure them however. Some complained of cold last night so that I had mattresses sent off to put on their cots today. Fullaway and Caum are living aboard ship. As there is not a great deal for them to do I have made no objection though I was not consulted in the matter. They are working under Ball and if he is satisfied I have no complaint to make.

Arranged for Ball to go off on the ship tonight and to use her in dredging tomorrow. A storm threatened this evening but did not materialize. Dickey went aboard to have a gathering in the lobe of his ear lanced and did not return last night. When rain came up I picked up his outfit and got it under cover. I find it almost impossible to write up my notes outdoors here because of the many birds standing or flying about. Inevitably my attention is attracted by the antics of the albatross or the ludicrous calls and attitudes of the shearwaters and before I am aware I have used fifteen or twenty minutes in amused contemplation of the avian activities transpiring on every side. The evening was cool so that I found a sweater and a coat comfortable. After an hour in the dark with David Thaanum, who had known Mr. Henshaw and others, I turned in. [Henry W. Henshaw was an eminent American ornithologist who collected extensively in Hawaii, mainly on the island of Hawaii, at the turn of the century (see Henshaw, 1902).]

April 10, Tuesday

The wind pulled and tugged at the tent all night last night and the moaning of the mutton birds sepulchral and ghostlike came continually. Day broke with a clear sky save for a band of cloud in the east that yellowed and then reddened in the sun. Inland I look out across a desolate waste of sand with a lagoon in the center so that I can imagine I am in a true desert but behind me if I care to turn is the beach with blue waves breaking into froth on the ribs of the reef.

A walk through the brisk morning air to the well for a wash was pleasant. White Terns hovered almost at my hand eyeing me curiously, while frigates and boobies swept overhead. A few Bulwer's Petrels are about at this time of day but soon disappear. As I finished washing, the sun came up over the clouds with promise of heat for later in the day.

After breakfast with Grant I walked up along the beach to the northern end of the island and then back along the lagoon inside. The coral sand of this beach is loose and fine and does not pack when wet like quartz sand so that it is difficult to walk in. It runs like water and at the cabin, when a trickle starts through some crevice from the bulked mass outside it is very hard to stop it. Toward the northern end of the island were masses of limestone, considerably eroded, ranged along like a roadway. In places the surface broke up over the edge of these, filling little ponds with water in which grew handsome green algae, as beautiful natural aquaria as I ever saw, that contained handsomely painted reef fishes. These, startled by our approach, frequently leaped over the ledge to the breakers five or six feet below. Terns were preparing to nest along here and in instances Gray-backs and Love Birds had eggs. Turnstones and curlew ran along the beaches. Turning inland along the sand we came down toward the lagoon. A patch of green proved to be a tract grown to tobacco, an area a hundred by two hundred feet where the scattered stalks, apparently proof against attack by rabbits, grew two or three feet high. Scattered little plants of the same species were noted elsewhere. Frigatebirds and boobies nested in the tobacco. I noted a second patch of *Sesuvium* along the lagoon and Mr. Fullaway brought in a plant of a legume, *Tribulus cestoides* [= *cistoides*, corrected elsewhere]. I collected a series of frigatebirds and was occupied during the afternoon in skinning and cleaning up. The day was clear and fine.

Mr. Ker informs me that seals come frequently to Midway, that he has seen ten there at one time, and in March 1922 they killed five. The ship worked back and forth all day gathering marine material in the drags. Toward evening with a westerly wind the surf increased so that boats could not come off. Three sailors sent ashore as a work party were marooned, as was Fullaway who had come off in the morning, so that I had to provide bedding for them. Specimens dry rapidly here in this atmosphere so that fears of humidity, on this island at least, were groundless. On the average, skins have dried as rapidly as on the desert. Salted rabbit skins put out this morning were dry enough to pack at noon. My seal skins are now half dry after a day's exposure in the air. In evening Dickey and I spent a pleasant hour in contemplation of the marvellous bird life about us.

April 11, Wednesday

Cool and sharp this morning when I awoke at six after a heavy night's sleep. I walked down for a wash and then wrote for a time. As I worked a Laysan Finch hopped curiously about within six inches of my elbow, eyeing me without fear whatever. I slipped up on a young frigate and caught it in my hand as it preened on an overturned frame.

This forenoon I worked north along the beach to the northern point of the island and then returned along the inner rim. At one point here were growths of *Scaevola lobelia* (formerly *Koenigii*) barely holding their own. Normally a shrub four or five feet high here, the plant merely protruded gnarled and twisted limbs above the sand, which had drifted in and covered their trunks. Only those persisted that grew near the crest of the slope that came up from the beach, where the sand was blown away from them to some extent. Most of the limbs were bare and denuded of bark. A few, still viable, produced scant bunches of elliptical fleshy leaves snipped by the rabbits or other agencies. To add to their difficulties a colony of frigatebirds were choosing nest sites among their scant limbs. For a considerable space along here the Black-footed Albatross was the most abundant. There were large colonies of Gray-backed Terns beginning to nest among the rocks on the beach. Curlew and turnstone were common and I shot one Sanderling. Returning along the lagoon I found considerable areas of quicksand near the water.

Was occupied in preparation of specimens during the afternoon. Made two Laysan Albatross into skins for the Bishop Museum which took two hours. Did not finish until dark. Received wire from Dr. Gregory approving revised plan for our field work on the trip in May. Also one from Admiral Simpson asking for a daily press bulletin! Sent the following off to Commander King:

> "U. S. S. TANAGER under Commander King has arrived at Laysan Island and members of the scientific party have been established in camp on shore. Investigations in different branches of science are well under way."

Mr. Caum has planted seed supplied me by Mr. Judd of ironwood *Casuarina equisetifolia* and milo *Thespesia populnea.*

April 12, Thursday

Completed the circuit of the island this morning by following the beach around the northern end. The reef throughout was close inshore with shelving rock forming the beach in some places. Throughout the island the outer beach slopes up to form a rounded crest from 100 to 300 feet from the water and then, after a more or less broad rounded summit, turns down into the inland basin that contains the lagoon. Everywhere was sand save for the buried stand of *Scaevola lobelia* on the northwest. The lagoon is strongly alkaline and morning and evening the shallow flats on either hand give off the characteristic reek of alkali flats lying under the sun the world over.

The temperature here is wonderful as the heat of the sun during our entire stay has been tempered by the steady trades. This forenoon it was as hot as at any time since our arrival but soon moderated. The dry atmosphere above the sand precludes excessive perspiration and during heavy work, morning and evening, the water content of the air increases considerably but I have no fears for my Kodak film that has been exposed.

The Black-footed Albatross occupies the outer slopes of the island on the northern side almost to the exclusion of the Laysan species. On the east is a tremendous colony of frigatebirds and a large group of Sooty Tern has come in there also. I returned past the patches of *Sesuvium* near the lagoon. The majority of the rabbits taken have been killed near here. I saw one female and killed her. She contained four developed embryos. Reno finds many of the rabbits not pregnant though some have contained as many as 9 young. The reaction upon the vegetation incident to the destruction of the bunnies is appreciable even during the four days that have passed since we came. The plant life and the lagomorphs apparently had struck a balance in which the rapidity of growth of the plants acted as an absolute check beyond which the mammals might not increase their number. With between 250 and 275 rabbits gone, the mat of *Sesuvium* is green and flourishing in contrast to its previous struggling condition.

Northward migration among the shorebirds is under way. What wonderful tales these sandpipers might tell of atolls and sandy shores seldom seen by man. This day like others has been clear save when flocks of fleecy clouds have passed across the sky. The clouds have the straight lined bases and fleecy tops of clouds in the areas influenced by the trades.

Made a list of supplies needed by the party on Laysàn during absence of the TANAGER to the westward. The boat did considerably more dredging today. Major Grant partly incapacitated today by severe diarrhoea. Had him remain in out of the sun. A party

of sailors from the boat secured nearly 75 pounds of crustaceans in less than two hours on the reef this evening.

April 13, Friday

This morning Captain Ingham and Commander King came ashore early and we made plans for leaving tomorrow. I was not able to get away until nine when I went up the beach and collected a series of three species of terns including a number of sets [of eggs] of *Sterna lunata*. The afternoon was occupied in caring for about twenty skins. Intensely hot with a blinding glare all day long. The buildings here are a great comfort to us.

At five thirty I began to assemble an outfit and at eight embarked on the TANAGER again. Left Dr. Ball in charge of the Laysan camp, with Reno, Dickey, Thompson and Schlemmer as his companions and Haig the colored boy remained as camp assistant and cook. On board, Commander King and I were occupied until ten o'clock in composing a little press bulletin for Admiral Simpson announcing progress. I sent a wireless to Gregory regarding the work and requested that he ask Mr. Judd to get seed of sand-binding plants for the second voyage of the TANAGER to be planted on Laysan. Wired the office announcing departure for westward and giving a few details of work. Slept in the upper deck with the ship rolling heavily.

April 14, Saturday

We were under way this morning at seven with three toots of the whistle, after some difficulty with the anchor chain, which had fouled on some coral heads. We stood away direct for Pearl and Hermes reefs. Laysan Albatross passed occasionally and many Black-footed Albatross hung over the wake. We saw tropicbirds occasionally and fair numbers of Wedge-tailed Shearwaters, though nothing like the number observed between Nihoa and Laysan. Weather was fine. I was seasick to some extent but not so seriously as on the start.

MIDWAY ATOLL (Outward)

April 15, Sunday

At seven this morning we sighted Pearl and Hermes reef. We passed close in and I had a good view of Southeast Island which showed a crown of vegetation. To the westward I was surprised to note two other islands nearly as large that were covered with vegetation on top. Black-footed Albatross came off to us in large numbers. At one time I counted fifty behind us. The Common Booby was also noted. Am feeling in good shape today and can now eat. At three we came in sight of the windmills on Midway and were in there shortly after four. The launch and another boat came out to greet us with several gentlemen and three ladies. Ours was the first boat that had stopped here since early January. I met the superintendent Mr. E. Desnouée and the manager Mr. Fraser. All were eager for talk and news. We had mail for them and some supplies. Mr. A. J. Ker, the New Zealander, left us here also. The visitors remained for tea and pulled out in time to get inside the lagoon by dark.

OCEAN ISLAND [= KURE ATOLL]

April 16, Monday

This morning we hauled out at six. Large numbers of Black-footed Albatross followed us out. At ten we raised Ocean Island and found a large island covered with vegetation. The surf broke heavily over the reef. We worked around to the southwest to the entrance of the atoll and spent some time in studying the situation from different angles. The available chart had been made by a British vessel in 1867 and though it showed soundings of 3 and 5 fathoms across an entrance nearly a mile wide, we were doubtful of their present accuracy. There was a high reef evident to the southwest with a submerged reef making in at an angle inside this. The heavy swells broke heavily at both these with a broad area between which showed clear at times but which again broke intermittently with small points of breakers inside. Commander King and I climbed to the crows nest but still were unable to get much satisfaction.

At three the self-bailing surfboat was put over and King and I went in to reconnoiter. Heavy ground swells were running and broke high on the reef. We worked in through the passage using a canvas drag without great trouble to find that the inner breakers were running on small coral heads so that it was easy to work in past them. We shipped no water, though a southeast wind made a nasty cross chop on the heavy swells. The rough water extended for a quarter of a mile inside the entrance and then became calm. Sand sharks were abundant. In fact, when the ship first anchored at least 500 swarmed around her in the water, ranging in size from four to nine feet. The men began fishing for them at once and one began shooting them with a service rifle, killing about 30.

As we passed over the reef first one and then another trailed the surfboat until we had 25 under us. As we came into the calmer water of the lagoon they dropped behind. The best passage led in past the point of the submerged reef on the east though the entire opening was nearly a mile wide. On the eastern side the water ran from three to four fathoms deep over coral with isolated points that rose to eight or nine feet from the surface. These are easily avoided. Once past the eastern point of the reef it was possible to work to the northeast, quartering over into the lee of the breakers into calmer water. Coral extended for about a mile and was then replaced by white sand over which the water showed a clear, beautiful green. Patches of coral were scattered all through this. There was a sand island half a mile long on the eastern side, a mile and half inside the entrance on which there were a number of Black-footed Albatross and three seals.

Beyond was the large island about three to three and one half miles inside and against the reef. We crossed to this, the entire passage requiring an hour and a half from the ship. Water ran from 6 to 12 feet deep all the distance and we ran the boat up on a broad sloping beach of coral sand. The entire island was grown with a heavy stand of *Scaevola*. I noted tracks of a rodent in the sand and saw six seals hauled out. We remained only ten minutes while I picked out a camp site and then returned, reaching the ship at seven. The swell outside had increased but we had no difficulty in coming out through the passage.

April 17, Tuesday

Started this morning at seven in the surfboat with Thaanum and Grant, with Caum and Fullaway in the whaleboat behind. The sea was calmer this morning with still a light wind from the southeast but as the ground swell was less we came in without difficulty through the passage though we were well loaded. In the morning light the large island appeared dim and distant, looming up merely as a dark line on the horizon. The lagoon inside was beautiful with its clear green water over white coral sand. Boobies and tropicbirds that passed overhead appeared a pale beautiful green instead of white, an

illusion caused by the reflected light from the water below in the low sun. Never have I seen such apparent wonderful coloration in the plumage of a bird and it was difficult to believe that they were not actually green.

Six seals were hauled up in sight on the beach and I shot two at once before the animals had been disturbed. As we came up in the boat I saw in several cases broad trails where the animals had hauled out of the water. One of those taken had crawled up over sixty yards to lie in the shade of the low bushes. I killed one with a neck shot and then took some photos of a smaller one. When approached the animals awake and utter a low whining call in an anxious tone like the sound emitted by a young puppy, while they raise their heads to look about. When approached too closely they open the mouth and make short rushes toward the persecutor while they utter an explosive barking grunt. Their progress is slow and may be likened to a caterpillar crawl as the animals hump and double in a clumsy effort at speed. My second animal, a huge male, lay asleep at the edge of the water. As I came up it awakened and, startled by my nearness made a lunge for the water. I fired quickly for the neck but the peculiar gait of the animal in which the head is drawn back and then protruded resulted in a shot in the ear and a broken skull that killed the poor brute instantly. Like the other two taken these bled copiously for a period of over five minutes.

Baggage was now unloaded and all hands began work of setting up the two tents brought off. I had the small 7 1/2 x 8 1/2 Tanalite tent that I used in South America, though now was the first time that it had ever had a pole in it. Hitherto it had been used in a forested country and had been put up with ropes alone. The tents were placed in a level space with a slight slope where the sand made a little embayment into the growth of bushes. I placed mine with the entrance toward the lagoon but Caum, Fullaway and Thaanum arranged theirs with entrance inland. Yesterday we left one water breaker ashore and a 25 pound can of navy bread and a case of roast beef that we had brought in case of emergency. Five more breakers of water were brought over with more food.

Figure 6. A. Wetmore skinning a monk seal on the beach at Ocean Island. April 17, 1923.

Grant in the meanwhile had begun work on the nearest seal. As soon as I could I joined him to find that he had the animal half flayed. We finished this one, the largest male, by noon. After a cold lunch from a can of tomatoes, two cans of roast beef and some hard tack, Grant started on a tour of part of the island while I rolled the second seal, also a male, down out of the bushes to a point where I got the sweep of the breeze near the water and began on it. Though very heavy to drag I was able to roll it over and over like a barrel without much effort down the gentle incline to the desired position. Grant returned in an hour with the mummified body of a gull found on the south beach that I do not recognize [see species accounts under *Larus*]. While we worked at the seal near the water's edge a living seal came swimming up around Mr. Thaanum who was collecting on a coral head a few feet off shore. It came then over to inspect Grant and I [sic] and swam along raising its head and breathing loudly. It crawled half out of the water blinking its eyes and occasionally looking in a puzzled way from Thaanum to us. I do not believe that the visual power of their eyes is very great as unless an object is moving they do not seem to make it out clearly.

At four another boat came in with Victor, a Filipino mess attendant, and cooking equipment, also another tent. We had planned to make this a rough camp and live on cold canned goods but, as the weather proved propitious, Commander King sent in the cooking outfit. The third tent was soon in place and camp fully established. Mr. Thaanum secured a shell today that he had not found previously north of Palmyra. About five the weather thickened and I asked Mr. Hyle, who had come in with the boat, to remain overnight. He thought best however to return. Soon after they left a rain squall came up but soon passed. An hour later the searchlight was turned on on the TANAGER and as it went out later I judged that the men were safe.

Black clouds lined the entire horizon and slight squalls of rain passed at intervals. The wind blew during the night so that the sides of the tent slapped steadily. Low waves washed on the beach below and I hear the steady roar of the heavy surf on the outer reef. At twelve and at three I rose and looked out to see the TANAGER still riding at anchor outside. I had thought that she might move to the lee side. It was so cold tonight that I found a flannel shirt and a hunting coat over my ordinary khaki shirt none too much to keep me warm. [A few historical notes from old newspaper accounts that Wetmore inserted here are omitted, as the events concerned are covered more fully by Woodward (1972).]

April 18, Wednesday

Cold this morning so that when I awoke at five thirty I shivered around for several minutes before I became warm. Innumerable rat tracks dot the sand among the bushes and for a short distance below in the open. Four traps set last night yielded three of the animals, small in size, slight in body, large rounded ears, sandy gray color, warmer brown than ordinary rats with long tails nearly naked of hair. Inland today several times I saw one running about in the vegetation with short runs that paused beneath protecting vegetation. One ran down a hole and I caught it in my hands. In evening several more were secured before we retired, in traps set just under the border of the bushes. [These were Pacific Rats (*Rattus exulans*), which may indicate that the island had once been visited prehistorically by Polynesians---an event for which there is as yet no other evidence. Rats were still common on Kure in the 1960's (Woodward, 1972)].

Grant found a corked bottle today containing a card with "Mrs. Maclurcan[?], Manageress Wentworth Hotel, Sydney" printed on one side. On the reverse was written "At sea, Great Northern, Feb. 18, 1917."

I cared for the rats taken first thing and a boat came off from the boat with water for us. Mr. Hyle took Thaanum and Fullaway over to the large sand island. They found it wholly bare of vegetation with ten seals, a colony of Black-footed Albatross and little else.

I walked down toward the sand spit to secure more seals. Fifteen were hauled out in sight with others reported from the opposite side and end. A careful estimate places the seal population at this atoll at 40 to 50 animals. I came across one male two years old that was just completing the molt. The old pelage hung to the back in broad patches where the hair was apparently being sloughed off with the epidermis, this being pushed off by the new hair growing in from below. The shed hair and skin came off in patches that show projecting hair ends on either side, a most curious appearance. The new hair was light in color and glossy and slick. I killed this animal with a neck shot.

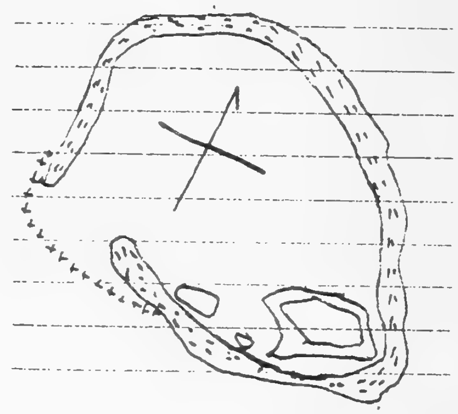

Figure 7. Sketch map of Ocean Island (Kure Atoll) from Wetmore's journal, apparently taken from a publication.

Beyond was a huge individual and I was delighted to find a female with a pup not more than ten days old. The female had hauled out to the top of the spit and had the youngster lying beside her. The pup was covered with smooth soft jet black hair. There was a faint tip of whitish at the extreme end of each flipper. The youngster was alert and active, saw me as soon as I came near and began to roll and trouble about arousing his mother who stared at me first and then threatened me with open mouth and a bellowing roar like that of a cow. I finally managed to get a shot at the youngster without hitting the mother though with difficulty. In spite of their seeming clumsiness these animals move the head with great quickness so that again I caught this animal across the back of the skull. The poor mother was much agitated and divided her time between nosing the pup and making lumbering dashes toward me. After a minute or two she rolled off down to the water and rounded up a yearling, apparently her last year's calf and finally herded it up out of the water a short distance away. Gave up her troubles as too much for her poor brain, dropped her head and went to sleep. A hundred yards beyond, a female had just given birth to another young as there was blood on the ground and the umbilical cord of the animal was just recently severed. Apparently this is one of the regular hauling grounds of the animals, a remote spot where with protection they may persist. We skinned the two taken by noon. Care of the seals occupied until two, when Caum, Fullaway and I penetrated to the center of the island.

In its general appearance the stem of *Scaevola lobelia* suggests that of an elder to some extent. It is irregular in growth, due to wind pressure on the young shoots and turns in spirals. The stems vary from a half inch to an inch in old specimens and have a pithy center. The broad, fleshy oval leaves grow in a clustered whorl at the tips of the branches. As the branches project at regular intervals in clusters radiating from the main stem the resulting leaf growth is heavy. Where protected from the wind in little valleys the shrubs grows dense and heavy, in exposed slopes it is scantier. The surface covered has been thrown up into irregular ridges. We found our way through these to the protected center of

the island where there were open spaces of irregular form grown with grasses, *Ipomea* and *Tribulus*.

Common and Blue-faced Boobies were nesting here and the loose sandy soil was absolutely honeycombed with petrel burrows. I was continually breaking through up to my knees and walking was exceedingly difficult. I killed eight Common Boobies in here and decided that with a few sets of eggs and other birds I had a load before I got out to the beach. In evening *Pterodroma hypoleuca* were flying. I killed three before dark and then shot 4 more on the wing by the aid of a flashlight after expenditure of considerable ammunition. Mists of rain passed at intervals during the day.

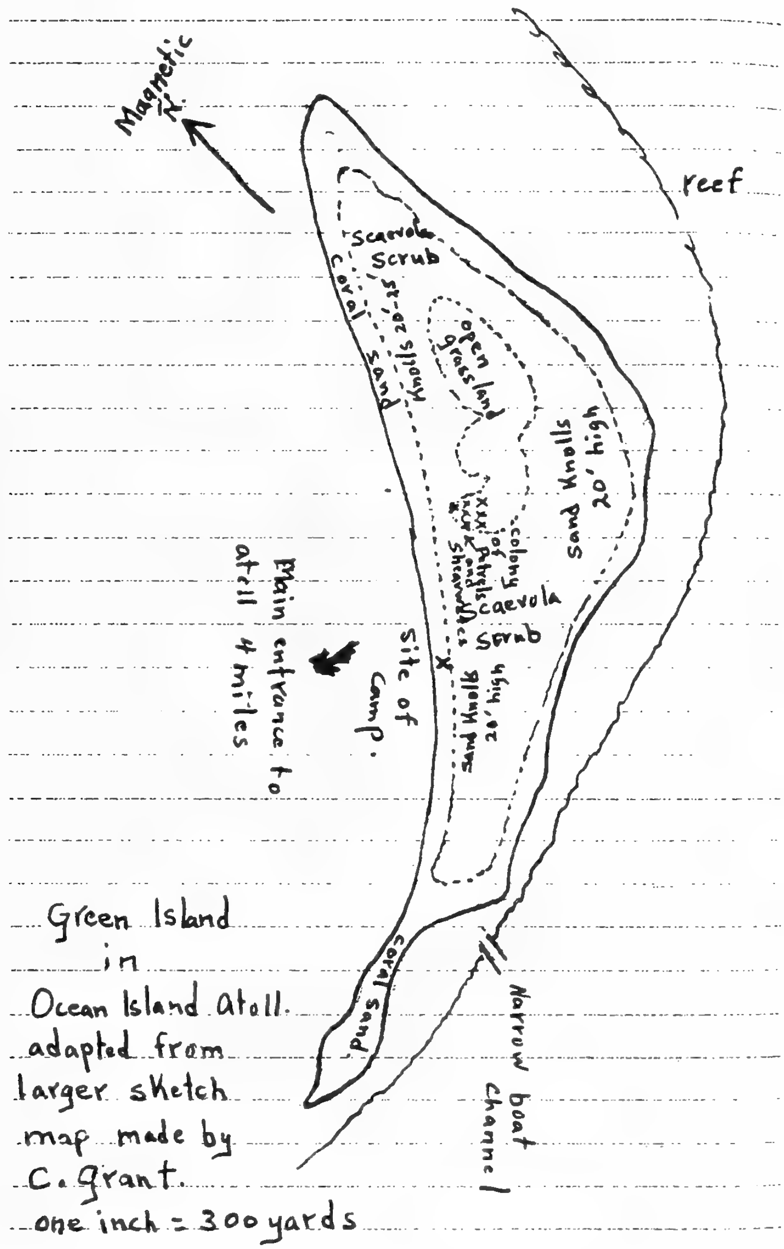

Figure 8. Sketch map of Green Island, Kure Atoll from Wetmore's journal.

April 19, Thursday

The northeast trades began again this morning after a warm and rather sticky night. It rained in small showers at intervals making it miserable work to prepare specimens. I had a large number on hand and was occupied with them most of the day. We rigged a tent fly between two tents and worked beneath it. Blow flies were numerous so that I had to protect the birds with mosquito netting. The wind was fresh and strong and made quite a wash on the beach.

In the late afternoon I walked out to the sand spit and secured some photos of seals which I hope may be good though the light was bad. The female whose calf I had killed bellowed at me as I passed, evidently associating me with her loss. Her yearling, hauled up on the sand, was so stuffed with her milk that he looked positively inflated. I came up behind him as he lay asleep and tossed small bits of coral and shell at him. At each impact he jumped with a writhing similar to that of some caterpillars, raising head and hind flippers but remaining stationary in the middle while he barked hoarsely. As the baiting continued he managed finally to wriggle over and face me and then redoubled his expostulation without however moving a foot to escape me. Beyond, I found the female with the pup born two days ago. To my surprise she led the pup into the water where it swam easily though at times it broke for the shore. The adult bellowed at me and occasionally nosed her pup anxiously. The young animal swam with head high but the female put her head through each wave. It is common for the animals to haul out up the long slope of the beach to the *Scaevola* bushes where they lie sheltered from sun and rain. Some of these places seem favored so that the seals had worn a groove at the resting place. As the animals are clumsy they cannot turn quickly but have to slide around gradually.

Figure 9. Dr. Wilson tries to lasso a monk seal. Ocean Island. April 16, 1923.

The coral sand beach is strewn with shells and I picked up a number as souvenirs. In evening I went out again for petrels but the birds did not fly out over the beach because of the high wind, or when they did come, passed so swiftly that I secured no shots. Cold and windy all night.

April 20, Friday

This forenoon I was occupied in making a survey of the shores of the island, completing the entire circuit. It was disappointingly uniform throughout. The projecting north and south points that have been bounding my world had held forth alluring promise of strange things beyond, which were not fulfilled. A sloping beach of coral sand from 50 to 80 yards wide led down from small rounded dunes to the water's edge. The dunes varied in height and contour but were all clothed uniformly with a growth of *Scaevola*, heavy on the protected sides, lighter toward the winds. On the west and north extends the broad waters of the lagoon, on the east and south the reef approaches closely to the island shore. The water between is studded thickly with heads of coral. There is a long open sand spit to the south and west a smaller one to the north. Some of the dunes pile up to 25 feet above the beach. Near the eastern part of the island is a level area covering one fourth the surface perhaps with sandy soil growth with grasses and creepers, with an irregular outline dotted with occasional clumps of the persistent *Scaevola*. Blue-faced and Common Boobies inhabit this. It is undermined by innumerable petrel burrows and shorebirds run over its surface. High dunes fringe it on the west and north, elsewhere the island is low. The dunes on the west and north extend along that entire side of the island.

Scaevola apparently gains a foothold on the sheltered parts of the dunes, and as years pass its leaves form a slight humus where not buried in sand. On this, creepers and grasses obtain root and gradually replace the original shrub, but only where protected. Such is the ecological succession on Ocean Island. We find no trace of the trees which were planted and which were to make this one of the best wooded islands in the Pacific.

Grant dug a hole in the depression in the sand dunes to a depth of 8 feet but found no water. The trades blew strongly today and the lagoon was roughened by waves. Huge combers stood up as an almost solid wall bounding our vision. At noon the TANAGER moved to a more sheltered anchorage in the lee of the island. At the neck of the western sandspit there is on the south side a narrow break in the reef and a short but somewhat crooked channel through which a boat may enter. The beach beyond is steep however and a landing may be effected only in calm weather as the waves pound on it heavily. There was heavy surf on it today.

I found twenty or more seals hauled on the eastern side, all fully grown males and females. Apparently young animals are restricted to the other side. The animals haul out clear to the bushes where, to make a comfortable hollow for their bodies, they depress the head and plow it under the sand clear to their ears while they hunch their huge bodies forward forming a rude trench 6 to 12 inches wide and four to ten feet long with the sand banked on either side. In this they lie, usually on the breast with head down and eyes closed, but occasionally on side or back. They are heedless creatures that spend most of their time ashore in sleep. If aroused the head is raised a foot or two while they gaze mildly around but if I stand still they drop back almost instantly, though I may be only ten feet away. If excited they uttered a low whine.

Their method of progression is curious. When really alarmed, head and hind flippers are both held raised a foot or more from the sand while the chest is hunched up, to

be followed by a rapid humping of the back which moves the pelvic regions forward a few inches to a purchase which enables a forward thrust of the forepart of the body for the same distance. These movements are performed rapidly so that they progress in a series of undulations curiously suggestive of the movement of crawling caterpillars. Progress is slow, though a ludicrous amount of effort is expended at the water's edge they usually pause to look back here feeling sure of escape.

The animals are now in pairs and males are fighting somewhat at suspected encroachers. The paired animals haul out together and lie near or touching one another. Mating, unlike that of the fur seal where the male is master of a harem and satisfies his desire at pleasure, seems to be a matter of complaisance on the part of the female, as females repulsed many of the advances of the male. Mating apparently took place at the water's edge in the slight wash of the waves or on the sand above. Males pursued intruders of the same sex, biting angrily at their hind flippers. To see how fast the animals could travel I walked quietly up to one and then kicked it in the rear. Aroused suddenly from a siesta after a full meal it gave one startled glance and then started full tilt along the beach, farting like a horse at every hump.

I had one curious experience with a male today. A pair had been disporting themselves in the surf and in on the beach, with the male busied in part with advances toward his mate and in part with angry rushes to repel rivals. The animals have been so inoffensive that I have paid little attention to them beyond a distance of ten feet. I shot two small noddies that fell in the water and began to float out. As there was four feet of water over a coral bottom, I stripped and started to go swim out to get my birds. When forty yards out I suddenly observed that the female seal, out of curiosity, had swum out my way and that the male was rushing me silently, submerged beneath the water. Fortunately there was a big coral head at hand and I secured shelter behind it while the male barked at me across it only four or five feet away. After four or five further feints which I managed to evade, though at a disadvantage because of the depth of the water, he swam slowly away after his retreating mate, pausing every few feet to raise his head and bark. Watching my chance I was glad to slip ashore, reaching the beach in time to escape a second attack. Though angry, I decided best to let the terns go.

At six this evening Grant and I crossed to the meadow after petrels. At dusk they began to appear and I was delighted to kill a fine *Pterodroma neglecta* [name written in later over "*Bulweria*"---see species accounts]. As darkness came on *Pterodroma hypoleuca* became common and a good many Wedge-tailed Shearwaters came out. When it was really dark the air was filled with dozens of the white-breasted petrels. I shot a good series by aid of the flashlight getting about one bird for every three shells. Frigatebirds and boobies alarmed by the noise circled until dusk when they settled, leaving only the petrels. On our return I rested for a few minutes to admire the strange scene. Imagine a small bit of land in the center of a great ocean with strange birds fluttering about attracted by the beams of light from our electric torches or pursuing one another with snarling cries. What scene could be more strange or alluring?

On our return, as we worked along an indistinct trail through the *Scaevola*, we came out on a ridge in sight of the ship as she lat at anchor a mile and a half away. Apparently a sharp-eyed quartermaster saw the flash of our torches, as immediately they began to fire white signal lights, sending up six at two-minute intervals. Mr. Thaanum, who, worried by my long absence had come out to look for us, and I walked down to the point and watched the ship for some time but as there was no further activity returned and went to bed.

April 21, Saturday

Bright and clear this morning with a heavy swell but the wind abated. At seven the surfboat came in from the ship and landed through the break in the reef on the eastern neck of the southern sandspit. The entrance here is about a hundred yards wide and is blocked in part by some large coral heads. It is, however, the best landing in ordinary weather. The beach behind is steep to and with an unfavorable wind carries a heavy surf. With a moderate tradewind the beach is safe, though boats should not be left here unguarded. The reef at this point is only a hundred yards off shore.

I took Commander King and Dr. Wilson across to the opening in the center of the island. The well dug by Grant showed alternate layers of fine and coarse coral sand but was dry throughout. The morning was occupied in preparing birds on hand and in the afternoon I collected a pair each of the two species of albatrosses, the only remaining species that we had not taken. The bird list here totalled 18 species not including the gull found on the beach. The mess boy and cooking gear went off in the afternoon and I sent in seal skins, skeletons, etc. After straightening out some miscellaneous odds and ends I walked across to the meadow and pulled up clumps of grass sufficient to make a large bundle to take back to Laysan for replanting.

Figure 10. Open meadow honey-combed with petrel burrows. Ocean Island. April 21, 1923.

The sun had then sunk and dusk was coming on. Frigatebirds sailed over their colony. Boobies returned from fishing excursions and a few turnstones flew out to the beach to roost. Wedge-tailed Shearwaters came in in abundance so that 300 or more were circling about at once. Later the Bonin Island Petrels appeared in great abundance. At dusk I crossed to the beach taking care to lower my flashlight as I crossed the dunes to avoid alarming the watch on the ship.

MIDWAY ATOLL (Return)

April 22, Sunday

Struck camp this morning and packed up. At seven a boat came off through the small passage at the south end of the island and we were embarked. The sea here was calm and smooth though it was still breaking heavily at the wide entrance to the atoll. We left at nine for Midway where we arrived at 1:30. Shortly after two the launch came out from the cable station and we were taken ashore to be hospitably received by Mr. E. Desnouée the Superintendent and Mr. Wm. S. Fraser who has care of the electrical equipment. Our collecting gear was deposited in a large boat house at the dock. Mr. Desnouée gave me a room in his own house and the other members of the party---Thaanum, Grant, Caum and Fullaway---were assigned quarters elsewhere. The island that houses the cable station was named Sand Island because of its original bare condition, well shown in a series of old photographs. The cable company has worked steadily to improve conditions. Quantities of earth have been brought down from Honolulu and a wind break of ironwood (*Casuarina equisetifolia*) entirely surround the grounds. The main buildings are of steel and concrete and are four in number with a grass-grown plaza occupying the center. Ornamental shrubs and flowers are distributed about and tree-lined walks lead down to the water. The whole forms a little oasis of green that entirely shuts out a view of the sand and is very restful to the eyes. An occasional glimpse of the clear green water of the lagoon gives a pleasant contrast to the grass and trees.

A vegetable garden at one side produces corn, peas, potatoes, beans, lettuce, tomatoes and similar crops. It is necessary to screen young plants against the depredations of Laysan Finches. Outside this forested tract the sandy wastes are grown extensively with *Scaevola lobelia* with occasional reaches of bunch grass and a *Juncus* said to have come from San Francisco [No species of *Juncus* is recorded from Midway by Wagner et al. (1990)]. In some of the older growths, *Scaevola* trees are 10 or 12 inches through. With the earth from Honolulu have come all of the usual weeds of Oahu. A little lighthouse on a high sand dune is said to be elevated 73 feet. The surface of the island is flat in general with rolling dunes on the east and south.

April 23, Monday

At daybreak this morning I was awakened by a beautiful chorus of canaries [a feral population of the Common Canary (*Serinus canaria*)---see species accounts] and Laysan Finches that continued until the sun was well in the air. I looked out to see a turnstone standing in the doorway of my room, which opens on a second-story verandah. A feeding tray hung on the railing is visited regularly by Laysan Finches and canaries while turnstones, Golden Plover and curlew run about on the lawn beneath and Laysan Rails scurry about in the shrubbery.

At seven we crossed in the launch to Eastern Island with a wind producing quite a chop. Five large porpoise (with long noses) appeared along side and I shot at one but missed. The water is shoal inshore at Eastern Island so that we were landed in a dinghy at the hook on the southern end. The island is level, with an elevation of only 12 or 15 feet. The broad portion is covered with *Scaevola* growing in a soil of coarse coral sand with openings leading through it. 16 or 18 donkeys run wild here, progeny of a pair brought from Honolulu nearly 20 years ago. In the afternoon sailors landed from the TANAGER made a drive and captured five by driving them into the water. One was brought aboard ship. The animals secure water for drinking by digging a few feet from salt water on the

beach. On this island the Laysan and Black-footed Albatross were abundant. Frigatebirds nested in a small colony in company with Red-footed Boobies, and the Laysan Rail and finch were abundant. A sand beach entirely surrounds the island on which I found turnstone, Golden Plover and a few tattlers. Gray-backed and Sooty Terns nested in the openings with a few *Gygis*, Common Noddies and Hawaiian Terns.

At eleven thirty we returned in the launch to Sand Island. The wind had freshened so that the lagoon was quite rough. The TANAGER had hauled around into the lee of the atoll. Grant and I were occupied during the afternoon in preparation of skins. The nights here are cold.

April 24, Tuesday

This morning I covered a good part of Sand Island filling in gaps in the birds taken yesterday. The wind continued strong. Laysan and Black-footed Albatross are common here and are tamer than elsewhere. The men take great interest in the birds and feed them and play with them. The young goonies are especially tame and do not resent being scratched on the neck.

According to Mr. Axelrod the White-tailed Tropicbird is seen here but rarely. None have been taken. Between 1906 and 1908 he brought the Laysan Rail from Eastern to Sand Island. The bird is now abundant on both. I was told that two geese with pink feet and bills and grayish speckled bodies had come here last year. Ducks of two species arrive occasionally. A larger form may be a Mallard and a smaller teal. All are much exhausted on arrival and after a time usually die. A small owl is seen occasionally as well as a small hawk. Mr. A. J. Ker described a web-footed bird, gray, with a knob on the bill. Mr. Glasspole in the cable office in Honolulu has a photo of it.

At four in the afternoon we bid our hospitable hosts goodbye and were taken in the launch to the southeastern entrance where the whaleboat met us and put us aboard the TANAGER.

PEARL AND HERMES REEF

April 25, Wednesday

At five this morning we were underway and came out from the lee of the island to encounter a stiff breeze and a heavy swell. I spent the forenoon in sleep to make up for time lost at Midway. About two we came to Pearl and Hermes reef and cruised along the southern side where we located a passage that would admit entrance to Southeast Island. The wind was stiff from the northeast and at dusk we returned to anchor in the lee southwest of the atoll. Old sailors say that the wind is due to the many sharks killed at Ocean Island. The Hawaiian shark god is offended and shows his displeasure in this manner.

April 26, Thursday

At five this morning we were under way and at seven the surfboat went over and we crossed to Southeast Island. The break in the reef here was two hundred feet wide with 3 to 6 fathoms of water. Inside, the water was shoal with many coral heads but immediately beyond Southeast Island the water deepened and was blue in color. The island is elongate about 900-1000 yards long by 500 yards wide, rising 15 feet above high water.

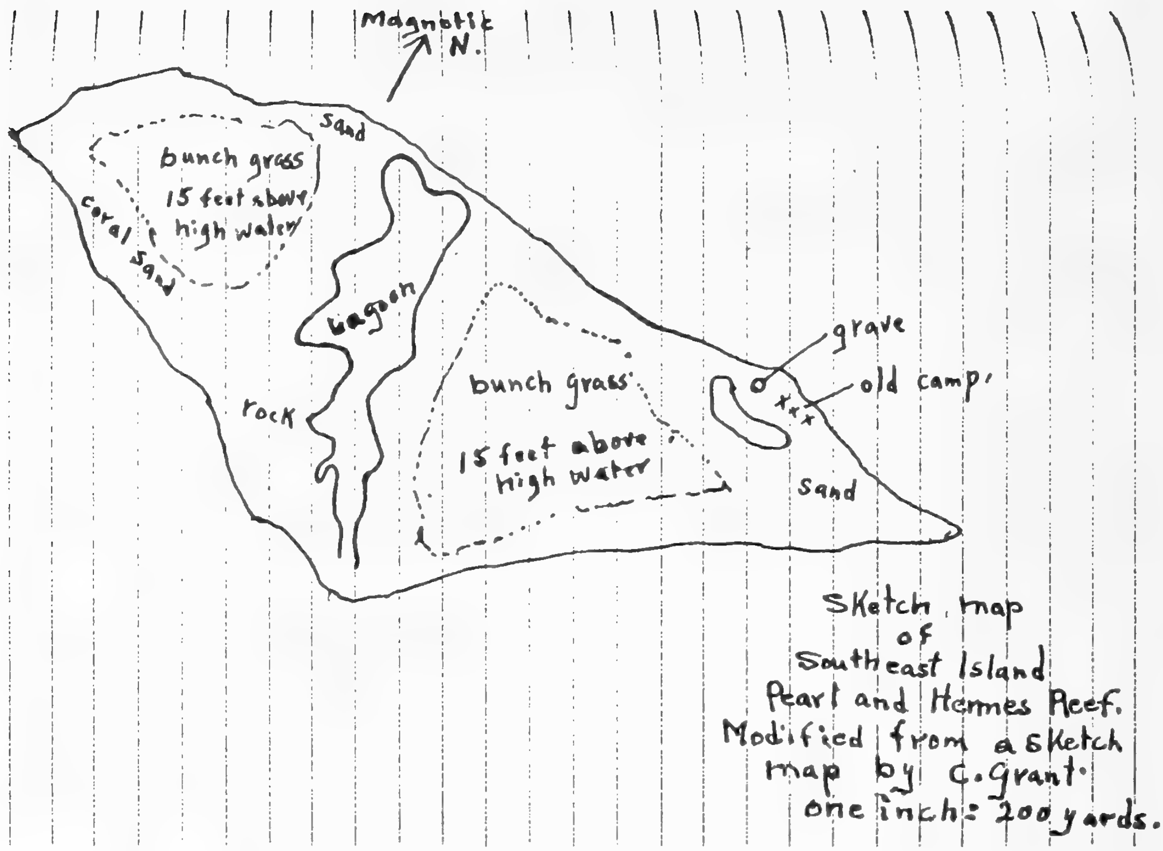

Figure 11. Sketch map of Southeast Island, Pearl and Hermes Reef, from Wetmore's journal.

On the western portion, the beach is of coral sand. Somewhat west of the center there is a tiny, irregular lagoon. A bank of limestone, blackened and eroded, forms the southern shore here and extends out in a broad hook to the eastward. The island rises between 10 and 18 feet at the highest point. Two ridges are covered with clumps of bunch grass one to two feet tall and a sprawling shrub with thick, rounded, hirsute leaves of grayish green color is abundant. There is a low spot with blackish soil on the eastern portion of the north side that evidently holds water after rains. It was now dry. Near this we found remains of an old camp. Upright sticks had apparently been used to support shelters of canvas and some rubbish, iron cans etc. lay about. Indications were that it was a camp of Japanese, perhaps from a wrecked sampan.

When we first landed we were astonished to find rabbit dung scattered about and later found the animals fairly common in the bunch grass. Apparently they had been introduced three or four years ago by the crew that had camped here. Indications were that the animals had come from Laysan as they were of the same size and mixed colors. I shot a considerable number, and Dr. Wilson more, so that we killed 25 before I was out of shells.

I spent part of the forenoon in working over the island. Shells were abundant on the beaches. As we came in we saw a number of dark round patches, solid black in color, three or four feet across in the water. Mr. Thaanum waded out to one and found it a solid mass of spiny sea urchins. Blue parrot fish were common along shore. I collected a good

many birds and after a solid meal of beef and egg sandwiches, Grant and I sat in the sand and skinned and salted them. They were wrapped in paper as they were finished and taken aboard ship, packed in a box that I found on the beach. The wind was strong and at intervals of half an hour or so heavy clouds formed, but after a flurry of driving mist broke away again. The air was cold.

At 4:30 we left the island and in a little over half an hour were again aboard ship. The TANAGER returned to her anchorage at the southwest end of the atoll. The tradewind blew steadily at 20 to 25 miles an hour all day. As rain continued during the evening, I slept on the floor in the wardroom after an evening of pleasant conversation with King, Ingham and the others.

April 27, Friday

The weather appeared threatening this morning but at five we started up along the reef again. As the sun came up the weather continued as yesterday with strong tradewind and continual mists of rain that did not wet us but that were a nuisance as the water continually clouded my glasses.

We passed in the surfboat through a broad break in the reef near the center on the southern side and after passing in far enough to get beyond the patches of coral heads near the breaks passed westward to the middle one of the two western islands, which lay about 1 1/2 miles to the westward. This island, without a name, I christened Grass Island. It is about 450 yards long to 100 yards wide, 15 feet high, surrounded by a beach of coral sand. The crest of the island was covered with bunch grass with a few of the shrubs recorded on Southeast Island. About 30 seals lay on the beach. A second sand island of small extent lay just east of it. As this island was small we remained here only from 8:40 to 10:45. On the shore of this island I saw a jet black skate 15 inches across feeding in the surf. When startled it rose from the bottom and with a flapping motion passed rapidly away.

Continuing with the strong tradewinds we passed on to the western island one and one half miles beyond, reaching it in about 40 minutes with the aid of the strong wind. We landed a few minutes before twelve and the sailors kindled a little fire on the beach to boil a pot of coffee. As cups were lacking we drank from large *Tonna melanostoma* shells picked up an hour before on Grass Island. Good containers but ones that did not cool rapidly. This western island I named Seal Island. It was also elongate, 600 yards long by 300 yards wide, rising 15 feet above high tide with a beach of coral sand and a point of limestone rock in the east. The crest was covered with the bunch grass with much of the grayish-leaved shrub. There was no sign of rabbits on either Grass or Seal Islands. This island was much more interesting than the middle one and we remained here until 4:30.

At 4:30 we started west again looking for a way "through" the reef, as it was out of the question to return as we had come, against the wind. A small break proved too shallow and after bumping over a number of coral heads we were forced to back out. A second trial a mile west was more fortunate as, after scraping over one or two places, we found a narrow lead that carried us out through the heads to the outside. The TANAGER had followed along all day and now met us as we were right at her usual anchorage. There were only occasional breakers along this western point of the reef but a bank of coral heads from 1 to 4 feet below the surface made a belt from 1/8 to 1/4 mile wide behind which the ground swell was broken. I secured a number of juvenile birds today and made them up tonight aboard ship.

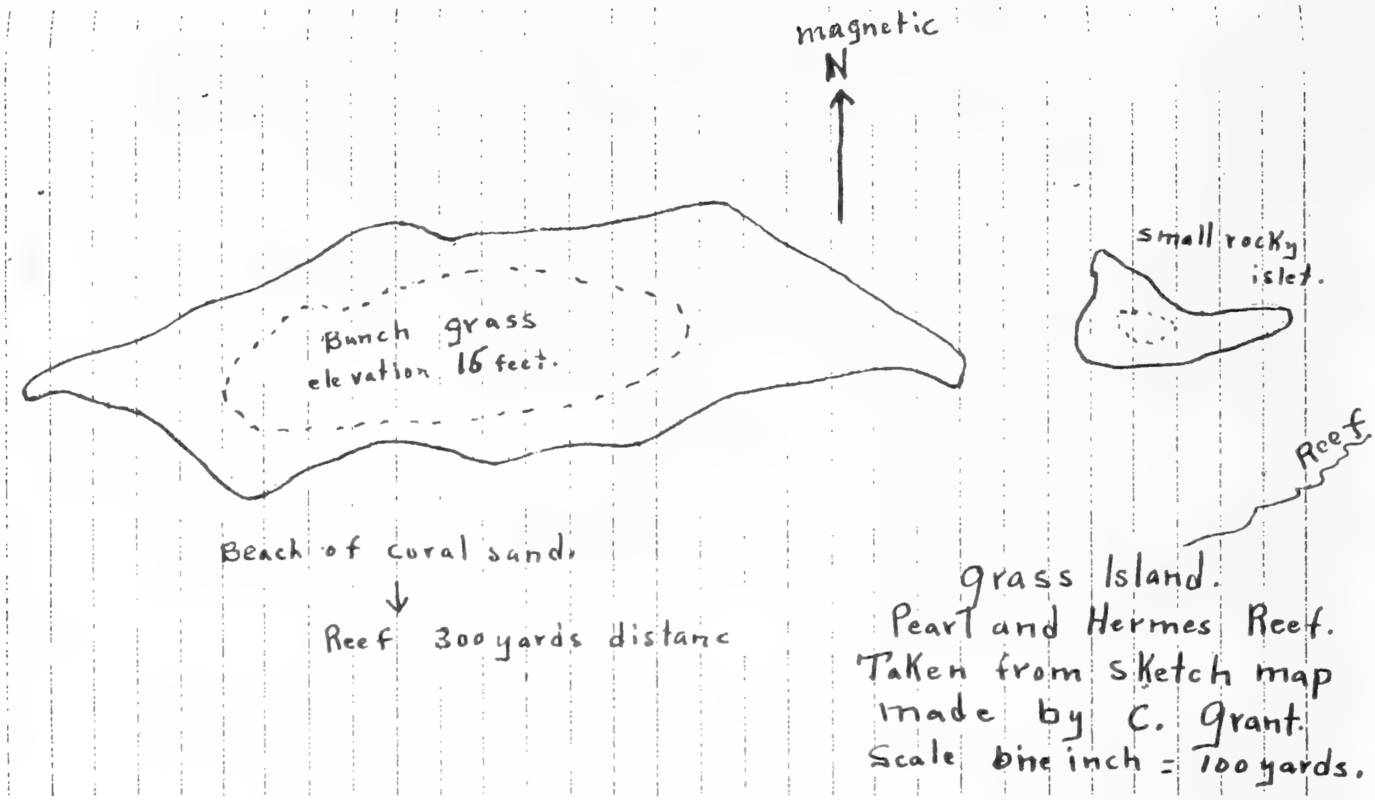

Figure 12. Sketch map of Grass Island, Pearl and Hermes Reef, from Wetmore's journal.

April 28, Saturday

This morning we disembarked again at seven at Southeast Island. Dr. Wilson went ashore and with three guns and several additional beaters we put on a rabbit drive over the entire island. The number killed today (and on the 26th) made a total of 90 rabbits. I estimate that perhaps 30 remain. The animals were wilder than on Laysan and usually ran as soon as they saw us. I killed all that I saw without compunction, whether sitting or running.

Men did some excavating under a pile of coral rock near the old camp and unearthed a human skeleton that had been buried in a box, now rotted partly away. The skull was apparently that of a Japanese 20 to 25 years old. Estimates on the age of the burial varied from 3 to 8 years. Additional study seemed to indicate that the camp was that of a crew of a wrecked sampan.

I killed a yearling seal here and one slightly older, getting them both [= each] with a single shot through the neck from the .38-.55. This seems the most effective place to hit them as it paralyzes them instantly. Of the eight that I have shot not one has moved other than to open the mouth or to roll the eyes. About 125 seal have been seen on the three islands explored here and undoubtedly more inhabit the islands in the northern part of the reef. In all I have actually seen 200 seals here and at Ocean Island in the past ten days. Stomachs of two taken contained remains of parrotfish.

The seal here haul out clear to the tops of the islands where they lie among the clumps of grass as usual always asleep. When disturbed they simply look about or roll their bloodshot eyes and if not actually threatened drop down at once and close their eyes. Often I pass within ten feet of them without disturbing them in the least. Most have scars on the back, perhaps wounds made by coral as they hunt for fish. Several times the animals have hauled out within 10 yards of a crowd of us as we sat on the sand. The last one that I shot bled copiously with its head in the wash of the surf so that the water was stained red for several yards. Another came up while I was sharpening a knife and, unmindful of the blood, nosed the dead animal curiously so that its head was covered with blood. They frequently have a green stain in the hair from some algal growth. In rapid progression they may elevate the front flippers or may use them to aid their movement. The rear ones are always folded together. Many times I came across them one hundred to two hundred feet from the water. Flies cluster about the vent, nose and the penis opening and cause them considerable annoyance. Their usual note was a curious whine like that of a puppy and they also uttered a threatening grunting bark. I was interested in noting that in moving about they passed around the young albatross, even though they had to make considerable detour to get around them. On one occasion one that I had alarmed considerably turned and searched for two or three minutes before it found its way through a colony of young goonies and on further tests I found that this was usual with the lumbering creatures.

At eleven thirty we left for the ship and shortly after noon were on our way toward Laysan. The ship is light as much of her oil has been burned and she pitched heavily.

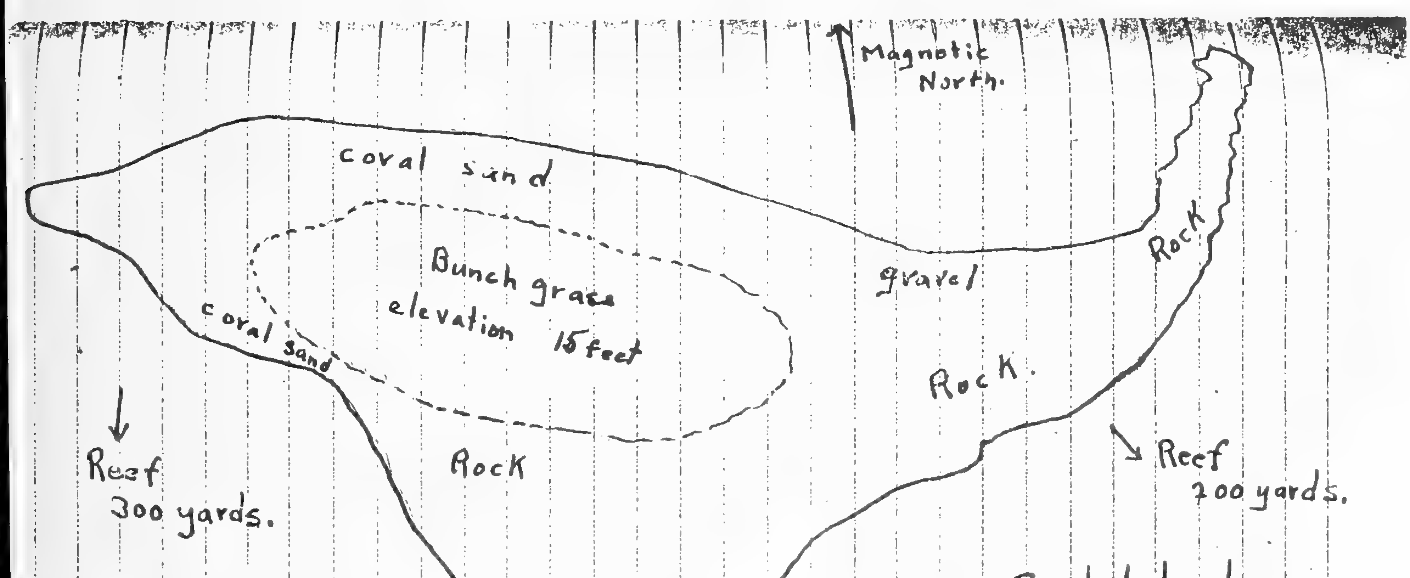

Figure 13. Sketch map of Seal Island, Pearl and Hermes Reef, from Wetmore's journal.

LAYSAN ISLAND (Return)

April 29, Sunday

We sighted Laysan about noon and at two o'clock were on shore. I was relieved to find all members of the party well and in good spirits. A high wind had occasioned a tremendous sandstorm that had held them storm bound for three days. Cloudy rainy weather had much interfered with Mr. Dickey's photographic work but he told me that he had a series that would illustrate the species found on the island at least.

Reno reported rabbits as very scarce. He had killed one the day before and shot another in the evening. Dickey and Schlemmer saw one today that escaped them. After we left, with the rabbits gone, a sprinkling of green vegetation appeared over the sand but was completely wiped out by the storm. Destruction to eggs in the tern colonies was almost complete. Food and water remained in abundance. With the aid of the steward I made out a small order for additional supplies wanted. In the evening we walked out and released 8 Laysan Rails brought from Midway. They were turned out near some freshwater holes in the *Sesuvium* patch where there was cover available. They were much frightened and scuttled about seeking cover.

April 30, Monday

Was occupied all day with the aid of Reno in packing specimens for shipment. Humidity has been such that nothing is thoroughly dry. Held over the two seal skins taken at Pearl and Hermes but sent in those from Ocean Island after resalting them and rubbing alum on the head and flippers.

Sent 8 boxes aboard ship to be forwarded to Washington by express.

1 box seal skeleton and skulls
1 box seal skins (five)
1 box bird skeletons and eggs
1 small box small bird and mammal skins
4 boxes salted bird skins.

I have turned over to Dr. Ball one good seal skin for mounting, a rat from Ocean Island, and ten bird skins, as indicated in my catalog. Dickey, Thompson, Caum and Fullaway return to Honolulu. The last boat went off at 5:00 p.m. and at six the TANAGER hauled out around the northern end of the island and left us alone. I remain in camp with Ball, Thaanum, Grant, Reno, and Schlemmer with George Haig as camp cook. We were all glad to sit and talk this evening.

May 1, Tuesday

C. Grant is now assigned to the collection of fish for the Bishop Museum. I have instructed him to take at least one specimen of every species and when practicable to put up three. Rare things in larger quantity. Eric Schlemmer will be my assistant from now on. This morning I had him plant five coconuts from the trees in front of the cabin and set out the grass brought from Ocean and Pearl and Hermes Reef. He reported that the albatross were very curious about it and pulled up part of it. He caught the rabbit seen yesterday and killed it.

I spent the entire day in cleaning up my collecting kit with assistance of Reno and Schlemmer, in labelling and cataloging odds and ends of specimens and writing notes. Tradewind blows steadily at about 20 miles an hour with considerable sand flying. It is decidedly warmer here than farther westward. Sky partly overcast but no further rain. The TANAGER left the dinghy for us, and Grant and Ball collected on the reef. I kept the liver and a cut from the loins of the yearling seal killed on Southeast Island at Pearl and Hermes and put them in the icebox aboard ship. The liver which we ate last night was excellent and tasted like good calf's liver. The steak was a trifle strong.

May 2, Wednesday

I worked on notes at night until ten and did not awaken this morning until twenty minutes of seven. The strong wind, which has prevailed since my return, from the southeast, moderated somewhat today. The sky was overcast with light clouds but sun broke through at intervals. Schlemmer and I walked south along the beach to the southern end of the island and then returned along the inner rim by way of the lagoon and guano piles. Ball and Grant were busy fishing all day.

The beach sand is much finer here than at at the islands at Pearl and Hermes reef where the shores lay 300 yards or more inside a broad fringe of coral that broke the force of any heavy waves. Here little of the sand was fine and frequently large areas were composed of broken fragments a quarter of an inch across. Here at Laysan the sand is fine enough to drift strongly with the wind. In fact sand here is finer than at Ocean Island in considerable part.

The Laysan Albatross have decreased in number at least one third since I left April 14. Turnstones, Golden Plovers, curlew and tattlers are in migration. Many Bulwer's Petrels have come in and we collected a series of fifteen from beneath rocks and from crevices in the limestone. Many more could have been taken easily. Practically the entire colony of *Gygis* have lost their eggs and a number have laid afresh. I collected a series of six. The ravages of turnstones and curlew in the tern colonies are exasperating in the extreme. I can see little hope for the bird colonies here until these robbers pass on northward.

The guano formerly worked here was of two kinds, hard and soft. It consists of coral sand impregnated with excrement and containing many fragments of bone and bits of egg shell. Some of it is consolidated to the consistency of soft sandstone. More can be crumbled between the fingers and some is simply loose. It varies from yellow to almost black in color and frequently has a strong odor. Schlemmer tells me that formerly they found entire eggs beneath the guano rock.

The amount of bird bones present here in the sand is tremendous. When the wind sweeps the loose sand from the surface, entire bones and bits of others dot the ground as far as I can see. Should this area become buried or consolidated it would form a wonderful fossil deposit. The majority of the bits are fragments of long bones. Occasional humeri, tarsi, tibio-tarsi and femora persist with extremities more or less worn. Metacarpi wear well as do ulnae and broken radii. Coracoids and sterna and pubes are usually much broken. Bits of crania or upper mandibles are less frequent. All are very fragile. I am struck by the comparison with what we find in fossil deposits.

In the frigate colony Schlemmer caught two males and after killing them I inflated them and ligated the trachea. The throat sac was dissected out in the afternoon. We put up the skins taken in the afternoon.

About five thirty we went in for [a bath] in front of the cabin. I was enchanted with the swimming. The water was agreeable; our little harbor had a sand beach with no coral. The bottom goes off steeply so that twenty feet out it is six feet deep. The shallow water to the reef is a beautiful clear green, beyond the deeper water is a deep purple. I wrote my notes in the evening to the accompaniment of eerie wails from the Wedge-tailed Shearwaters the screams of terns, and little barking calls from the Bulwer's Petrels.

Figure 14. A. Wetmore and Eric Schlemmer return from a forenoon afield [carrying frigatebirds and a booby]. Laysan Island. May 5, 1923.

May 3, Thursday

Warmer this morning with only a moderate wind. Heavy clouds hang around the horizon but it does not rain. I walked out with Schlemmer along the north shore and then returned via the lagoon. *Scaevola lobelia* is found along the crest of the hill above the outer beach in some abundance, the shrubs projecting as little points of apparently dead limbs that rise from four to ten inches above the sand. In spite of their dry dead appearance these twigs carry life and are producing little leaves, many of which have been blighted. Reno killed a rabbit here last night. On the slope immediately above the lagoon rise innumerable little plants starting from unsuspected seeds. Unless weather conditions prove unfavorable again, the vegetation should be fairly intensive here in a month or two. The albatrosses have pulled up much of the sand [sic = grass] that we have planted.

The trip along the beach showed little of novelty save that we found two turtles. One had crawled out to sleep and let me walk up within ten feet to photograph it, though it moved its eyes and finally raised its head. It did not offer to bite though we touched its head. When turned over its front flippers waved wildly for a few minutes and then it settled down to an attempt to turn over. Female; Green Turtle, *Chelone mydas*. On progressing hurriedly over firm sand the animal uses the same flapping motion of the front flippers that it does in swimming. On coarser gravel it is restricted to a crawl.

Reno tells me that during the heavy sand storm all of the albatross and shearwaters went out to sea, leaving the young albatross to battle the storm as best they might. About one third of the albatross, those without young, have failed to return. Today I counted 34 humeri of albatrosses in a space 10 x 15 feet on the summit of a dune. This did not include other bones, which were in abundance.

The afternoon was busily occupied in caring for skins. At a quarter of six Reno, Thaanum and I went in for a swim. As the day was warmer than average recently, the water felt cool at first but after the first plunge was pleasant. The reef closely invests the the entire island with one extensive lagoon. I found a specimen of *Puffinus gravis* [sic = *P. griseus*, see species accounts] washed up on the beach today, apparently the first record for the Hawaiian Islands.

Puffinus cuneatus is howling and yowling with redoubled noise outside the door tonight. Poor Mr. Thompson was greatly disturbed by the noise of these birds and used to stand out and clap his hands at them in an effort to silence them! In which he succeeded only in awakening the rest of us with no effect whatever on the birds.

Last night I had George cook the breasts of a frigatebird and found them dark in color and rather coarse grained, not unlike wild goose, very good. Tonight I tried *Diomedea nigripes* but did not care for it so much as it had a sweetish taste. Grant came in with a locust crab [locust lobster, Scyllaridae], a curious flattened beast with flattened foreshortened and greatly modified antennae and no pincers. Its eyes glowed with a bright orange color in reflected light. Crayfish, *Palinurus japonicus* [= *P. panularus*], abound on the reef and grow to 12 inches in length. The sailors from the TANAGER caught over 75 pounds one night, sufficient to feed the entire ship's crew. The flesh is sweet and very good.

May 4, Friday

This morning Schlemmer and I crossed the island and completed a circuit by following along the eastern beaches. The reef here was joined to the shore and in some places breakers shot high in air at every wave. [Illegible word] wreckage from a sailing ship was supposed to have come from a schooner wrecked six or seven years ago on Maro and Dowsett Reefs. Much warmer today with clear sun most of the day. Small shrubs, apparently dead, projecting only a few inches above the sand are throwing out a few leaves and little plants are starting over the sand, and the *Sesuvium* patch is prospering. I thought I detected a rabbit track in one place and Schlemmer killed one later under a rock pile. In the evening Reno took another. I collected a series of immature frigatebirds and a box of eggs of the Sooty Tern. After an afternoon occupied in preparation of specimens a dip in the water was refreshing. The evening was cool and pleasant and I sat for some time watching the birds.

May 5, Saturday

This morning I made a circle of the lagoon returning to camp at noon. This carried me through the colonies of Laysan Albatross and frigatebirds. Kept careful watch for any sign of rabbits without detecting any. The sky was overcast with a light haze. Worked until dark on specimens secured.

May 6, Sunday

Sky overcast for most the day today but still warm. In early morning I went out with Schlemmer and collected some albatross and other birds. The afternoon was occupied in caring for birds, packing eggs and in waiting. At five thirty we had a dip in the water. The sky is nearly always heavily obscured in evening in the west so that we see no brilliant sunsets. Tonight it was especially black and heavy, the water below being equally inky in color though that inside the reef was clear green as usual.

At dusk with Schlemmer I crossed to the *Sesuvium* patch and sat against a pile of rock waiting for darkness and watching the marvellous bird life about me. Wedge-tailed Shearwaters swarmed both in air and on the ground, Christmas Island Shearwater were common, and as darkness came on Bulwer's Petrels appeared and with soft calls clambered over the rock piles. As they passed I had a whiff of their petrel odor. One came over and looked over my coat sleeve in its search for a nesting burrow. When darkness had come on, we went out through the bird colonies armed with our search lights. Shearwaters were present in innumerable hordes and blundered against us at every turn. I had to walk carefully to avoid treading on them. Sooty and Gray-backed Terns turned their backs to the light while Golden Plover, turnstone and curlew walked about uncertainly. Any could be picked up at will. The Laysan Albatross paid little attention to the light but were frightened at their own shadows, especially when they wavered or flickered in the dancing light. After some search we found the teal in a small salt pond and captured four. Going was bad here as the ground was soft and quivered like jelly but we got out without difficulty. Schlemmer brought in a bag full of live curlew, plover and turnstone which he released in the cabin where they blundered about uncertainly.

May 7, Monday

Sky heavily overcast today, wind south of east, somewhat cooler. As visibility over the sand was excellent because of lack of glare from the sand, I made a trip around the

the inner basin and made a count of the young Laysan Albatross now present. At the same time Reno counted the *Sula cyanops*. Reno had put out several blocks of poisoned alfalfanear rock piles where the last of the rabbits seem to be hanging out. Counting birds and walking across the sands here is precarious business as at every ten steps I step into a covered petrel or shearwater burrow. Schlemmer and I have discovered the remains of stumps of 2 palm trees northeast of the lagoon. I have seen these figured in old cuts. In the afternoon I put up six teal and found them very fat and greasy. I skinned them, cut off the excess fat with a sharp knife, applied alum to the heads and then salted them. In the evening the sun broke through partly and gave us a beautiful rosy sunset masked in front by a heavy bank of black cloud. After a half hour of amusements in listening to the caterwauling of the shearwaters I went in and worked on my notes.

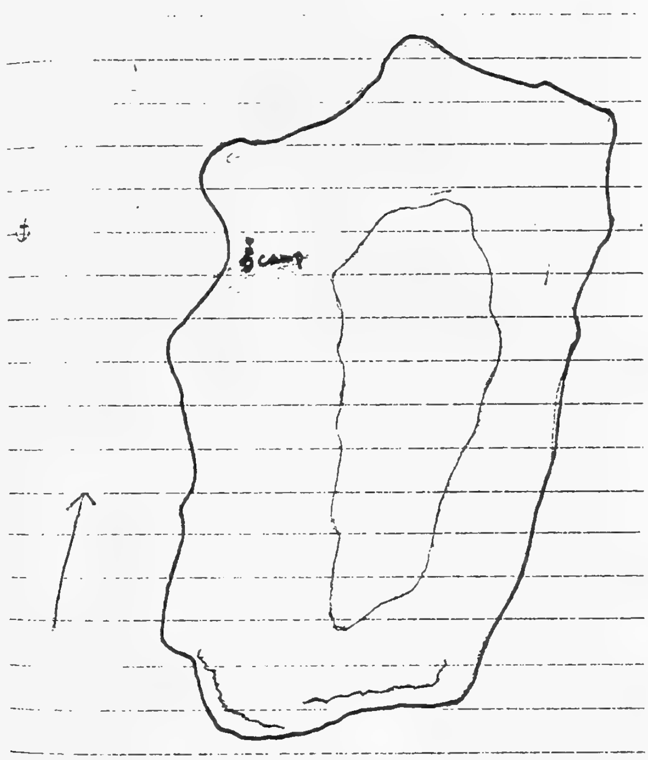

Figure 15. Sketch map of Laysan Island from Wetmore's journal.

May 8, Tuesday

Awoke this morning to find a slow rain falling which increased until a considerable volume of water fell during the forenoon. We caught water in pails and barrels until all available containers were filled with fresh sweet water. Sufficient birds were on hand to occupy the forenoon together with notes. The weather cleared somewhat toward noon and in the afternoon I made a trip around the entire island with Schlemmer to complete a count of the young albatross. We returned at five. At the northern end of the island we found three small turtles hauled out and collected one for the table. I kept the shell, which was an unusually perfect one, as a souvenir of Laysan. (9/27/69. The shell is on the wall in my library at home.) [note added later---this shell is still in the possession of Mrs. Wetmore]. Shearwaters were unusually noisy during the night kept us all awake more or less. During practically our entire stay here the wind has blown from a little south of east except for brief periods when it has hauled in the west. The heavy rains had packed the sand today so that walking across it was easy.

May 9, Wednesday

This morning I walked south along the shore and made a count of the terns in the tern colonies in this direction. Gray-backs and Love Birds are laying again after having been drowned out during a storm two weeks ago. Many tiny shells are found in the wash of the waves at high tide and I picked up some beautiful ones. Also found many ophiurans here. Returning, we crossed through the Black-footed Albatross colony on the eastern side to collect a young bird that I had marked down the day before. The weather moderated by

noon though rain had threatened earlier in the day. Work on specimens covered the afternoon. Toward dusk I walked down to the *Sesuvium* patch where I was joined later by Reno and Schlemmer who had been out for rabbits. Wedge-tailed Shearwaters fairly swarmed and I find many more albatross down here than during the day. We collected a series of terns and then returned to camp.

May 10, Thursday

Today I remained in camp all day caring for specimens taken yesterday. I have been making up specimens for the Bishop Museum recently to fill their list of desiderata as I have good series of practically everything now. Weather calm and beautiful, warm.

Table 3. Thermometer readings in degrees Fahrenheit, Laysan Island, 9 April to 13 May 1923. Taken by Charles E. Reno, Biological Assistant.

Date	7AM	Noon	6PM
April 9	68	79	70
April 10	63	76	71.5
April 11	62.5	78	68
April 12	65.5	74	70
April 13	67	89	78
April 14	69	76.5	70.5
April 15	67.5	79	70
April 16	67	77.5	69.5
April 17	68.5	81	73
April 18	71.5	82	73
April 19	71	85.5	75
April 20	72.5	82	71
April 21	69.5	76	70
April 22	69	85.5	81.5
April 23	66.5	67	68.5
April 24	65	69	65.5
April 25	64	69	64
April 26	67	74.5	69
April 27	69	76	70.5
April 28	69	78	69.5
April 29	72	83.5	74
April 30	71	76	73.5
May 1	72	80	71.5
May 2	71.5	82	72
May 3	72	80	76.5
May 4	76	82.5	72
May 5	75	81	72.5
May 6	72.5	80	74
May 7	70.5	77	72
May 8	71.5	76	71.5
May 9	71	82	76
May 10	76	81.5	78
May 11	79	79	75
May 12	78	71	70.5
May 13	68	71	72

May 11, Friday

This morning Reno, Schlemmer and I routed [sic] at 4:45 and separating visited the three localities where rabbits may still be expected. Was greatly pleased when we did not find any. None have been seen now for about five days. Reno has used poisoned sweet potato in deep holes in rock that might harbor rabbits and has put out chunks of poisoned alfalfa in areas where rabbit were last seen. We have been hunting steadily for them during the day and toward sunset in the evening. Only six or seven have been killed since my return from the west and only one seen has escaped. We presume that that animal has been killed by poison since persistent hunting has failed to locate it. Growth of vegetation has been remarkable considering the absolutely barren conditions of the island when we first landed. Seeds whose presence in the sand was wholly unexpected have sprouted and bits of green are appearing in many places. The *Scaevola* along the northwestern shore, almost buried in sand, has put out new shoots and has grown many new leaves so that where protected from the wind it looks quite thrifty. The *Sesuvium* has grown to a great extent and a new plant, a pigweed-like affair with pale green leaves that grows from a somewhat woody stem is coming in among the other plants. Apparently this was a favorite plant with the rabbits, as before it was entirely absent. On the inner slope of the island basin toward the lagoon are many plants of a crucifer with a heavy two-spined seed. These are barely above the surface now but promise more extensive growth. A shrub along the shore south of camp is also putting out new leaves, though the stems appear badly chewed by rabbits. Unless sand storms interfere, vegetation should again appear to a considerable extent within the next few months. Recent rains have favored germination. The sand seemed to hold a considerable amount of moisture at all times. The well dug on our first arrival has cleared and is now palatable, though somewhat yellowish in color. It was dug six feet deep and has about two feet of water in it.

As I left camp this morning day was just breaking. Most of the albatross had gone to sea to fish but there was much activity among the shearwaters. I walked up along the shore to the northern end of the island and then cut back inland to the big *Sesuvium* patch. Recent rains have made a number of pools here of fairly fresh water. Selecting a point of vantage near these I sat quietly for nearly an hour watching for possible rabbits and enjoying the life about me. Two Laysan Teal waded about for a time in one of the pools and then came over and went to sleep in the sun within forty feet of me. A Laysan Finch hopped all about me at a distance of four feet peering up curiously and then coming up behind hitched slowly up the fold in my hunting coat until it reached my shoulder and then startled flew away. Shearwaters were all about. The Christmas Island species sought the shade of the rock piles as the sun came up. Myriad Sooty Terns kept up their continual clatter while the Hawaiian, Gray-backs and noddies in smaller numbers were in the foreground. Behind me the Blue-faced Boobies squawked hoarsely at intervals.
The *Sesuvium* has a tiny flower that exhales a scent pleasing to the nostrils. In early morning I can sometimes get this odor at a distance of half a mile.

The lagoon today lay calm and smooth as a mirror. The terns gathered beyond in close order, or hovering above their colony, were clearly reflected in its waters from our camp beyond. After a later breakfast than usual I was occupied with specimens for the rest of the day. Toward dark I crossed to the *Sesuvium* patch again. Heavy clouds lay to the westward but circled past to the north. As the sun sank the waters of the lagoon were tinged a beautiful pink that faded to a sombre black as the storm clouds loomed higher. The wind has piled great masses of foam along the shore and strong stench came from the water whipped by the wind. I had intended to remain out for a time but with a quick shift in the wind the storm clouds loomed higher with a heavy threat of wind and rain. Eric and

Reno I knew were away so that I hastened back. Two Blue-faced Boobies that I had taken bring somewhat of an impediment to my progress. A mist of rain came as I reached camp. Eric came to meet me and I was relieved to find that the specimens on hand were all protected by canvas. Rain increased with a driving inshore wind. All hands turned out and with considerable labor pulled the heavy dinghy up on shore were it was safe from the steadily increasing swell.

May 12, Saturday

Surf was heavy this morning breaking clear across the opening opposite camp and piling high on the reef on either side. We had specimens to care for early in the morning and then prepared seven boxes for packing specimens. Rain came off and on during the day so that I postponed packing salted skins until weather conditions were more favorable. Packed a lot of eggs and renovated the collecting outfit in general.

Grant came in at supper time and reported a large seal, sighted first last night, as still asleep. Dr. Ball wanted the animal for the Bishop Museum so that after supper we walked across the island to it and I shot it. The bullet struck squarely through the spinal cord apparently, as the animal merely jerked with the first shock and then was dead save for a faint muscular palpitation over the body. Like others seen it was lying asleep. It had scooped a furrow with its head three feet long and a foot wide to receive the breast and lay prostrate as usual. We rolled it higher on the beach to avoid the surf and in its new position I was able to appreciate the value of the furrow, as on the level sand, pressure on the breast arched the neck and back vertebrae to an extent that must have been uncomfortable. The animal was a female and very old as the teeth were much worn. The mouth cavity gave off a disagreeable odor when opened. There were a number of scars on the body apparently from coral.

This afternoon Schlemmer and I took a cruise over the lagoon in the life raft. The water contained a heavy concentration of salt, nearly to saturation apparently. Cuts on my hands burned from it and as the water dried it left an encrustation of salt on the hair on arms. Brine shrimp (*Artemia*) were as abundant as I have ever seen them and occurred everywhere in shallow water beyond a depth of six inches and everywhere that it was deep. The northern and southern end of the lagoon are deep with a shallow shelf extending across the middle. Dr. Ball found 23 feet the maximum depth in the southern end. I was unable to reach farther with a twelve foot pole in the northern part. The basin was floored largely with a hard limestone over which was drifted more or less sand. Near the shore particularly near the east and north, the side of the prevailing winds, were quantities of bird bones lying on the bottom. On examination I found these firm and solid and very well preserved. The contrast with bones lying exposed on the open sand where the sun had full play on them was especially marked, the latter being much worn and brittle so that they frequently crumbled at a touch. Those in the water had been more or less eaten by crabs before their deposition but subsequently had been free from all attack and from decay. Those found in sand covered at times by the salt water were also well preserved. Such a formation would lead readily to fossilization. It may be noted that humeri, ulnae, tibio-tarsi and metatarsi predominated, with a good many femora, metacarpals and vertebrae and occasional fragments of skull, sternum or pelvis, the relationship in abundance being about as in avian fossils. (A sample collected were all *Diomedea immutabilis* identified 9/27/68) [note added later].

Ball and Fullaway have seen a shrimp-like creature an inch or two long and very swift in movement in the lagoon that no one has collected as yet. At dusk I spent some

time in the tern colonies at the *Sesuvium*. Shearwaters swarmed everywhere so the in the dusk the ground appeared black with them.

May 13, Sunday

Was occupied with specimens for a time this morning and then wrote on notes for a considerable period and did other odds and ends. Rain squalls passed at intervals and things were damp and disagreeable. At three I walked down the beach to the blowhole. Heavy surf was running and tern's nests all along had been destroyed. But others are being made. From here I crossed inland to the lagoon for a last look for small passerines and rabbits. The tern colony was of interest as always and I paused to examine many of the young albatross.

I was interested in comparing a young *S. cyanops* and young *Fregata* both about 24 hours old. The former, born on the ground, was partly clothed in down, had the eyes closed, and though it called and moved about showed no inclination to climb. The latter, from a stick nest, had its eyes open, was silent and showed a distinct tendency to climb by hooking its head over my finger and by grasping with its feet.

Shortly after six the TANAGER was sighted and at 7:30 with a toot of her whistle she came to anchor. The passage was rough and no boat came off but it was comforting to see her lights again.

List of resident birds [seabird data removed to Table 5].

Anas laysanensis	count	14
Porzanula palmeri		2
(8 others brought from Midway and released)		
Himatione (three seen before storm)		0
Millerbird (one seen?)		0
Telespyza cantans		100

I estimate mortality among young albatross at 50% so that on this basis there should be 13,600 adult *Diomedea immutabilis* and 18,800 adult *D. nigripes*. I cannot see that there has ever been room for many more. The matter can best be checked by a count at the period when eggs have been deposited.

May 14, Monday

Last night I propped a lantern on a water breaker in the door of our room to serve as a beacon for the TANAGER and assure them that they were not drifting ashore. This attracted many Wedge-tailed Shearwaters who squalled loud groans to such an extent that I did not get an over amount of sleep. A boat came ashore before seven with mail and as my first task I had the painful duty of informing poor Reno of the sudden death of his wife. Naturally, he was much broken up over it and the news cast a gloom over the entire day for me. We began loading at once and by three o'clock everything was aboard ship. I remained ashore until six to go through my mail, write a few necessary letters, and look about for things that may have been overlooked. The little finches hopped about enquiringly and I gave them a little pan of water to drink. The male albatross came wandering up for a curious look around. Our camp here had a tremendous amount of gear ashore so that in all 14 boat trips were made before passengers and freight were aboard. Commander King and I prepared rather a lengthy press notice tonight. I am told that the

papers have been printing every word of what we have sent in, although some of the statements are scanty. Interest among residents of Honolulu seems strong in the expedition and its purpose.

Mr. Gerrit Wilder came off today with a great quantity of seed and seedlings secured through C. S. Judd, Executive Officer of the Board of Agriculture, and I sent out Eric Schlemmer with him to show him suitable places for planting. Two sailors carried the seed. Following is a list of the material received.

Calophyllum inophyllum	Native Kamani	1 gunny sack
Barringtonia asiatica	Botong (In P.d.)[?]	2 " "
Casuarina equisetifolia	Lowland Ironwood	2 pounds
Thespesia populnea	Milo	5 "
Pritchardia pacifica	Fiji Fan Palm	10 "
Leucaena glauca	Ipil-ipil, Haole koa	26 "
Haematoxylum campechianum	Logwood	3 "
Ipomea pes-caprae		
Beach Morning Glory (Pohuehue)		1/2 "
Scaevola frutiacus[?]		
Beach Naupaka (Naupaka Kahakai, Huahekili[?]		1 pkt
Hibiscus tiliaceus	Hau seed	1 "
Hibiscus tiliaceus	" potted plants	9 plants
Hibiscus tiliaceus	" branches	40

I went aboard at six after a last look around at the shacks now lonesome and empty. At seven we hauled out and stood off to the west and north. Mr. Wilder who was on Laysan 18 years ago tells me that he sees no marked decrease in the numbers of albatross now over the conditions then.

LISIANSKI ISLAND

May 15, Tuesday

At seven this morning I found that we had been travelling slowly toward Lisiansky during the night with increased speed after daybreak. Frequent mists of rain obscured the horizon and made visibility poor. An occasional Sooty Tern or Laysan Albatross passed and many Black-footed Albatross hung over our wake. Wedge-tailed Shearwaters were common. What seemed to be a peculiarly marked *Sula leucogaster* appeared about 15 miles off the island and followed us nearly in. The back and wings were sooty, the head was usual but there was a broad white collar entirely about the neck. The bird circled the ship frequently so that I had several good views of it. [A page on the discovery of Lisianski was inserted here but duplicates information in Clapp and Wirtz (1975) and is omitted].

About ten we sighted the island and came in toward the northwestern side, with caution since the original survey for the island had been made in 1805, with the corrections later. The island seemed a barren sand spit save for a dark line along the northern end that might represent vegetation. At twelve we were about three miles or perhaps a little more off at anchor and shortly after one Commander King and I went over in the surfboat with Schlemmer, G. Wilder and Thaanum. The motor-sailer was put over, loaded and followed us in. We found 4 to 5 fathoms of water over the entrance and practically all the way in to within a quarter of a mile from the island. The bottom was partly coral and partly sand.

We came in through the southern boat passage and found three feet of water clear in to the beach.

After landing I picked a camp site about 175 yards from the water line. The beach sloped gently here and though the first elevation was safe enough it showed evidence of water with storm or other exceptional tides so I deemed it expedient to cross a little depression to a higher slope where a smooth expanse of sand was comparatively free from shearwater burrows. We walked across then to an old building, now fallen in, and by our return the motorboat had come in with the remainder of the party and the bulk of the camp equipment.

I sent Reno out to look for rabbit sign and the others except Wilder, Thurston and one or two others turned to and made camp. We put up four tents in a row facing west, toward the beach. My experience at other points has been that this is most satisfactory, as prevailing winds come from the east-southeast or northeast and with these striking the rear of a tent the canvas does not whip so badly as when it strikes the entrance. There is absolutely no protection from wind on these low, barren islands and tent pegs hold in the sand with difficulty. A drizzle of rain came in before the tents were fully pegged but we were able to get bedding and perishables under cover before harm was done. Reno came back with report of no sign of rabbits so that he went back aboard the TANAGER. I sent in a message by him to the office stating that camp had been transferred to Lisiansky, rabbits gone on Laysan and that Reno desired to return when the boat went in about June one.

Arrangement was made with Commander King to take Reno to Pearl and Hermes reef and to put him ashore on Southeast Island which he will poison thoroughly to destroy remaining rabbits. He will work from the ship but will land for three consecutive days if practicable. The TANAGER put out at seven thirty and was soon out of sight. Camp was fully established and we were ready for work. Rain continued through the evening at intervals. Insects and plants are so scarce that Dr. Gregory has not deemed it expedient to send out a botanist and entomologist for this trip, particularly since I have asked him to hold the parties as small as possible. [Personnel list omitted---see itinerary].

The party landed here for this camp consists of Wetmore, Schlemmer, Ball, Thaanum, Grant, Baker, with George Higgs as cook. Wilder, Thurston, Dranga, Reno and Lawrence, who were ashore for a few hours in the afternoon, have gone on to Pearl and Hermes, as has Jones.

May 16, Wednesday

Sky overcast this morning and continued so during day. A heavy shower passed at eleven o'clock and two or three others during the afternoon. Everything dries so rapidly that I have made no attempt to change [clothes]. Wind south to southeast. Temperature 7:00 a.m. 72°, noon 74°, 6:00 p.m. 73°. George the cook is downcast over the loss of his cook shack at Laysan but is serving us excellent meals. We bought a new oven for his oil stove (Perfection Oil Stove No. 62) and we had a peach pie this noon and a spice cake tonight.

After breakfast I walked around the coastline of the northern two thirds of the island in a preliminary survey. As charted, the island seems very accurately delineated. It is roughly a parallelogram a mile (nautical) long by slightly less than a half mile wide. A low ridge on the northeast coast marks the highest point and there is a central depression

bounded by a raised rim protecting it from the ocean that must, in an earlier stage of development, have been the basin of a lagoon similar to that at Laysan.

The only vegetation on the island is a narrow strip of grass, and a pigweed of perhaps two acres in total area that extends along the ridge above the beach in a narrow line at the northwest point. Elsewhere the place is absolutely bare. An examination showed that denudation had been due to rabbits as I found parts of skeletons in small number scattered about, considerably worn and weathered. Careful examination revealed no sign of living animals so that the statement that the rabbits here ate up their food supply and then perished, apparently is correct. I examined vegetation carefully for signs of cutting and looked for dung but found no indication of either.

Wedge-tailed Shearwaters were spread over the entire island, as at Laysan, and were the most abundant bird. Laysan and Black-footed Albatross were fairly common though not so abundant in proportion to the area available as elsewhere. The grass tract naturally was the focus for bird-life and here I found a colony of Gray-backed Terns, many Sooty Terns, frigatebirds, Blue-faced Boobies and Common Boobies. A few Christmas Island Shearwaters were scattered about with the other species, noddies are fairly common and I see a few Hawaiian Terns. One Love Bird appeared last night and *Sula piscator* is fairly common. Such is a brief review of the bird-life. I was surprised to encounter another of what is apparently the gray phase of the Wedge-tailed Shearwater and then another. Eric saw one of them and attempted to point it out to me among a cloud of flying birds. I finally located one with a gray breast and shot it only to find it another. In all I took four, and two or three more were seen.

Mr. Wilder last night encountered a seal asleep in the grass and I looked for it this morning, finding it without difficulty, lying on one side in a depression. As I approached, several terns fluttered out across it and it raised head and flippers in protest. The skin in these animals seems very sensitive as it reacted to the slightest touch from wing or foot of a bird. I killed this animal with a neck shot and found it to be a young female in full molt on the dorsal surface with the old hair adhering in large patches to the back and new short hair coming in beneath. The animals have a beautiful silvery sheen to the hair when they are just shed. The teats in the female of this species number four and are arranged at the the corners of a quadrangle with the scar of the umbilicus in the center as shown below. They are slight depressions in the skin. In the present animal the posterior ones were approximately 120 mm apart, the anterior ones 150 mm and the anterior and posterior mammae were separated by approximately 180 mm.

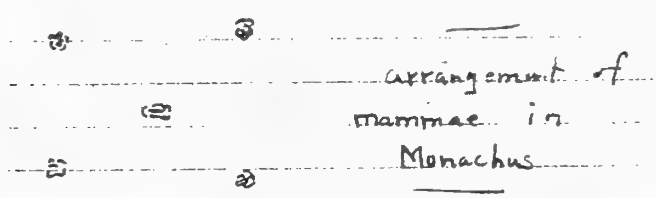

Figure 16. Sketch of arrangement of mammae in Hawaiian Monk Seal (*Monachus schauinslandi*) from Wetmore's journal.

Apparently this animal had not moved from its position assumed the night before. The stomach was filled with the fish known as manini [a surgeonfish, the convict tang, *Acanthurus triostegus*]. Digestion seems somewhat slow in these great beasts and from recent observations I believe that when they have secured a full meal they haul ashore and

often remain there asleep or resting for as much as two days, if not longer. Toward dusk Eric, who had been out along the beach, came in out of breath to announce another. He took the rifle and killed it.

The weather cleared in evening with promise of a good day tomorrow. I spent the time until dark in writing in my notes and some similar work.

May 17, Thursday

This morning I was out at six and found a promise of better weather in the air though clouds hung about the horizon. Temperature 7:00 a.m. 74°, 12 noon 72°, 6 p.m. 76°. As the sun rose the sky cleared, though the wind still remained in the southeast.

We went down at eight and skinned the seal killed last night. It was a male, apparently between two and three years old, that had shed into fine fresh pelage. It is much easier to skin these animals when fresh than after rigor mortis has set in, as the flippers stiffen so that it is difficult to force them apart because of the near proximity of joints to cut on the inner sides. Like all others, this animal had the body overlaid by a coat of fat 1 1/4 inches thick, certainly superfluous so far as heat is concerned in this climate. I cut out the heart of this animal with the larger vessels leading from it, and preserved it for dissection. The blood is very dark and the heart small in proportion to the bulk of the animal. After completing the seal we moved things out of our tent and set them in the sun while we raised the sides of the tents to dry out the sand. The sun, which shone throughout the day, was welcome, as things would soon begin to mould.

Many birds pass the site of our camp here and in the afternoon I shot a number for specimens. We also caught part of the albatross needed. Both Laysan and Black-footed Albatross are not overly abundant and, as on Ocean Island where similar conditions prevail, they were rather wild. The Black-footed was especially wary and only one was secured. Details of caring for skins, labels, and storing of specimens occupied me until nearly dark. Our accommodations here are such that I must pack my salted skins in boxes as they are completed, with layers of excelsior between to give them ventilation.

At dusk Schlemmer and I walked up to the grass plot to look for petrels. The air was soft and balmy and many strange stars came out in a deep purple sky. Walking across the flats is difficult as one steps through a shearwater burrow every ten feet on the average. Conditions are not much better on the beaches as there the coral shell sand does not pack, even when wet from the wash of the waves. We sat on the beach for half an hour looking out across a stretch of dark water with a quarter moon hanging in the sky. Terns chattered behind us and I had only to turn my flashlight behind to see dozens of the Sooty Terns standing over their eggs. Frigatebirds beat past with many Wedge-tailed Shearwaters, and occasionally a Bulwer's Petrel was seen. We came across a huge female turtle above high water mark and Eric turned her over to wait until tomorrow. We looked carefully through the grass and in half an hour had secured five Bonin Island Petrels. Frigatebirds flapped up heavily and boobies were dazed by the glare of our lights. Terns chattered at us and turned their backs but many did not fly. I stepped carefully over and among them to avoid injuring them. At ten we walked slowly back along the beach to camp. The visibility was such that sharp watch was required not to miss the tents.

Turtles are enormously abundant here and occur especially in certain bays. Algae grow in great batches in quiet sheltered water three or four feet deep and here the animals browse with no enemies save the sharks. As they feed, they thrust the head to the surface

at intervals for air and then go down again. As we came in to land with our camp equipment, dark spots on shore occasioned considerable comment. We saw finally that part were turtles but one bunch of spots were supposed to be rocks. Later I saw that the "rocks" had gone as they were all turtles lying thickly on the sand beach. I counted 80 at that point in a distance of 300 yards, partly on shore and partly feeding in the water, ranging in size from 15 inches to 4 feet long. At certain points 25 or 30 hauled out to lie together close to one another or even with large ones partly covering small ones.

Figure 17. David Thaanum collecting shells on Lisianski. May 18, 1923.

May 18, Friday

Slept this morning until six thirty after my trip of last night. It was very damp this morning but the day was again clear and hot. On arising I walked out for a dip in the water [which was] pleasantly warm in the cool morning air. The water runs out four or five feet deep for some distance off, with coral heads on either side of a little sandy entrance---little waves washed the fine sand along the beach.

Some young and immature birds taken last night needed attention and work on these occupied the time until nearly nine. Following this I walked up to the grass plot and Eric cut off the head of the turtle for me that we had taken the night before. This animal proved to be a female nearly ready to lay, as she contained fifty eggs with the shell and a large number of others not yet covered by the membrane. We found these very good eating. This animal had the posterior margin of the shell smooth. The shell measured [left blank] long by [left blank] wide. I prepared the head as a specimen. Another killed by Captain Grant had dentations on the posterior margin of the shell and was a male. It measured [left blank] long by [left blank] wide. Some of the turtles are more or less

scarred on the flippers probably by sharks. I saw one yesterday at over 200 pounds weight with the front flipper cut off raggedly and the end of the ulna projecting.

The grass plot here contains about 3 acres and is arranged in a long semicircle along a ridge above the beach. With the grass are one or two other plants. This is the only vegetation found on the island. Apparently roots persisted here until the last of the rabbits died. The grass is extending slowly, held down more or less by birds breeding on the tussocks. There are none of the small land shells (*Partula*) usually found on this vegetation on all these islands, but Mr. Thaanum has discovered the dead shells in some abundance in humus held beneath large lumps of coral that have been cast high on the ridge and have been in position for many years.

Very hot today but a dry heat that was welcome as it favored the handling of specimens. At work all the afternoon on skins. At dusk Dr. Ball took the skin and head of a large ulua (*Carangus* [= *Caranx*]) to the beach to wash it before putting it in alcohol and was astounded to have a small shark snatch it from his hand.

May 19, Saturday

Strong sunlight this morning with a hint of rain squalls in the offing. Temp. 7:00 a.m. 72°, noon 74°, 6 p.m. 70°. The island of Lisiansky is highest on the north and west where it rises in a rounded slope to about 40 feet above sea level. To the southward it slopes away to a rounded central basin that is encircled by a low rim separating it on all sides from the long reach that stretches to the beach. This central depression is now dry but probably was formerly the site of a lagoon as at Laysan. The island thus may be older than Laysan as its lagoon has entirely filled in. The soil is sand with a strong infiltration of guano that compacts the earth and stains it brown in many places. On the higher slopes this has formed a firm crust that either stretches as a smooth hardened surface or is eroded in pits. On the eastern side is a low stretch of limestone rock that projects along the shore.

At the southern end of the central depression is the remains of an old camp, apparently of Japanese construction. Originally there had been a shed here with a galvanized iron roof thirty feet long by 12 feet wide. One or two small structures stood nearby. The larger structure had now blown over and only a few posts marked the sites of others. About 30 five-gallon coal-oil tins lay at one side buried in sand with top or sides eaten away by rust. That the camp had been made by Japanese was attested by the method used in construction and by ideographs found on stray bits of board nailed to old rafters. It had been abandoned seven or eight years ago if not longer.

Our camp is located on the western side toward the southern end of the island. On the beach near it was the frame of an old whaleboat. On the eastern side of the island near the south end is part of an old sampan and a ship's dinghy. The earth is undermined by shearwater holes so that walking is difficult. This morning I crossed past the old camp to the eastern side and collected some shorebirds and terns. Numbers of turtles were hauled out here, one of them a female with one flipper bitten off leaving the ulna projecting from an open wound. From here we continued around past the grass tract to camp.

The TANAGER was sighted a little before ten and the motorboat landed before noon. On the first trip no dinghy was brought off and the boat could not get to the beach because of the surf. Passengers had either to swim or wade ashore. Commander King and Captain Ingham came off and we made arrangements for further work, after which I worked on specimens. It is cool and pleasant under a tent fly but very hot in the sun. Grant and

Thaanum went off to the ship this evening with as much other gear as we could spare. Mr. Wilder remained ashore with me and planted a number of *Barringtonia asiatica*, a tree that is said to do well in sand. The evening was cool and pleasant and after the sun sank I sat for some time watching the graceful flight of the shearwaters and the movements of the albatross. Wrote letters and worked on other papers until ten thirty.

May 20, Sunday

Was out this morning at five and found rain falling. Completed packing but left the tents up until eight to permit them to dry as much as possible. The motor-sailer came in then and we loaded up and went aboard ship. About ten the TANAGER pulled out slowly and headed out past Laysan. The sea was calm and smooth.

GARDNER PINNACLES

May 21, Monday

We passed to the westward of Laysan during the night, going far enough north to clear Maro and Dowsett reefs and then turned eastward heading for Gardiner [sic passim]. Weather clear and fine and sea smooth. About six in the evening we passed a small sampan and turned in near enough to determine that it was the TAIYO MARU X368. The boat had made a landfall on Gardiner Island and was now standing away toward Maro and Dowsett. Japanese watched us silently as we came near uncertain of our intention. When the Captain had made out the name and number of the boat to his satisfaction he gave the order to turn off to our course and as we fell away the men waved and shouted, evidently in relief. The boat was a fishing vessel from Honolulu, here over 600 miles from port. Shortly after, Gardiner Island was sighted from the mast head and at dusk the mass of the two rocks of the island could be dimly made out on the horizon. We came in slowly to an anchorage about a mile to the southwest. Rain squalls obscured the rocks at times and again they could be made out thinly by the light of a small moon. The summit of the larger one appeared white as snow apparently from guano. The ship rolled gently at anchor during the night.

May 22, Tuesday

Though Gardiner Island seemed dim and distant in the faint moonlight when I turned in last night, at daybreak this morning it loomed close at hand, as we were anchored about a mile away. At the end a small rock was separated from the main mass. Above this rose a rock 170 feet high with a deep cleft [left blank] of the center and then a lower peak. The large island was about 200 yards long. All examined it with the eye and with glasses, with many speculations as to the possibility of getting ashore, as according to the pilot notes the rock was inaccessible. Blue-faced and Red-footed Boobies, frigatebirds and terns came out to circle about us and among the latter I was pleased to see a few *Procelsterna saxatilis*.

The sea continued calm with a clear sky. Shortly after seven all of the party were embarked on the whaleboat and the surfboat and went across to the island. At first sight it appeared steep and precipitous and in spite of the relatively calm sea a heavy swell washed the rocky base or surged up in foaming crests that dashed against the steep walls. Near the base of the great cleft in the main island was a somewhat gentler slope with two large rocks resting against one another at a right angle at the water's edge---in one side of this space was a rock ledge a foot wide and three or four feet long. As the surges well in, the water

came up almost to the ledge and then after two to five seconds dropped down again. At frequent intervals heavier swells broke and dashed up over the higher rocks with a heavy wash. Under the direction of Commander King and Mr. Hyle, the surfboat edged in slowly to give opportunity to study the landing. As the boat rose in a heavy swell it was allowed to drift in against the rock and Schlemmer, who was in the bow, jumped ashore. Instantly the order "stern all" was given and the boat backed back a foot or two while the water fell away beneath it. A minute later we came in again and I sprang ashore to run up the rocks before a heavier surge came in. Thus were landed Dranga, Thaanum, Wilder, Ball, Dr. Wilson, John Baker, eight of us in all.

Figure 18. Landing from surf boat. Gardiner Island. May 22, 1923.

Once ashore progress was not difficult. Though the sides of the rock were steep they were eroded out so that progress was only a matter of climbing up over series of ledges. The summit was gained without particular difficulty and with Schlemmer I climbed down to the water's edge both on [left blank] and [left blank] sides. Dranga had previously landed by swimming on the smaller rock. We worked here until nearly twelve when rising seas made it imperative for all to get off. The rock of the island was volcanic in nature and black in color. I noted occasional lumps of a crystal in the heavier mass, the crystal seemingly being of calcite as it was soft. The entire upper third of the rock was colored white by deposits of guano.

As I landed I found colonies of noddies with Gray-backed and Sooty Terns and searched eagerly among them for *Procelsterna*. The the first fifteen minutes I was afraid that I was mistaken in my identification of them in the uncertain light of early morning as none appeared. On crossing, however, to the smaller peak I was pleased to find two resting on a ledge and soon secured them both. A climb over a shoulder to the higher peak revealed tropicbirds nesting below the summit and many Blue-faced Boobies, most of them with well grown young. It was necessary to clear the adults away ahead of us as they were belligerent and had a way of coming up behind and striking that was disconcerting, when one was on a steep pitch, to say the least. I searched carefully among the rock crevices for petrels but failed to find any.

Spiders were common under rocks and I saw several large earwigs. Half a dozen plants of a pigweed were seen but no other vegetation was found. In working about I frequently got thorns in my hands apparently from some seed like that of the spiny seed from Laysan but saw no plants that might yield them. *Tribulus cistoides* [this evidently added later]. The lower reaches of rock where washed by waves were covered with algae with many of the conical shells known as opehi [= opihi, limpets]. The animal of the latter makes an excellent chowder but is too tough to be eaten itself.

We returned at noon and remained at anchor until nearly 9 p.m. in order to shift oil. This gave welcome opportunity to prepare skins and to pack up a series of specimens for shipment to Washington. Schlemmer, Reno and I worked steadily until after seven and were tired when the labor was finished.

May 23, Wednesday

This morning, with a southeast wind, we passed north of French Frigate Shoals so far away that the islands were out of sight. Laysan and Black-footed Albatross were common, with *Gygis*, Gray-backed and Sooty Terns, Wedge-tailed and an occasional Christmas Island Shearwater. Necker was passed at dusk with many birds about.

NIHOA ISLAND (No landing)

May 24, Thursday

This morning at nine we were in sight of Nihoa and toward noon ran up past the high cliffs at the western end to examine Adams Bay which opens to the south and southeast. Steep slopes ran up from the beach to the abrupt cliffs that break to form the northern shore. Three small bights formed the inner face of the bay. A sand beach lay in the westernmost which, with a shoulder above the middle bight, seemed to offer two sites that might be available for camping. Because of a southeast wind, surf was breaking heavily in the bay, precluding any attempt at landing. We ran up far enough to see the opening through a tunnel cut through at the eastern end of the island and then turned and sought anchorage in the lee at the western end of the island a little over half a mile distant.

After lunch Commander King put over the surfboat and with Thaanum, Dranga, Schlemmer and Grant and myself went in to the foot of the cliffs. The rock wall towered from the water's edge sheer to the summit from 370 to 900 feet above. The black volcanic rock at irregular intervals was cut by the somewhat sinuate seams made by dykes of harder rock from 6 inches to two feet broad that extended vertically by the rock face. At one or two places this intruded material had filled some cavity, forming an expanded shield like a medallion. The summit supported by these harder materials was cut in huge triangular

dentations. One pinnacle of rounded form and erect position of a suggestive form was known as Ka Ule Na Na Hoa [Ka-ule-o-Nanahoa]. According to legend, in the old days a fisherman lived here who in his family had a daughter of great beauty of form and person. The renown of this handsome young lady came to the ears of a prince of Kauai who came across and requested her in marriage. The old fisherman told the royal suitor to consult the girl's wishes in the matter. She ran nimbly up the steep slopes to escape his warm advances until finally she came to the edge of the cliff far above the water. Here she paused, warning her would-be lover not to touch her or she would leap over. His ardor overcoming his reason he continued to advance and she jumped to her death while [he] was changed to stone, the pinnacle rock representing his erect penis, Ka Ule Na Na Hoa---the male genital erect in a marital position. In another version of the story the chase begins in the eastern islands and continues westward from island to island. The girl trapped finally on Nihoa, the last land to the westward known to the Hawaiians, leaped to her death. The remainder of the tale is as above.

To continue---three or four caves have been driven by wave action in the base of the cliffs. As we passed, heavy swells rose and fell in them with hollow mysterious slapping and booming in the hidden depths. After landing Grant, Thaanum and Dranga on a broad rock ledge to search for shells, Commander King himself guided the surfboat back for a distance of sixty feet into one of these caverns. The end was barely visible 75 to 100 feet beyond. The water runs from 6 to 8 fathoms clear to the base of the cliffs and was 7 fathoms deep in the entrance of this cave. On the rocks outside were abundance of the shells known as opihi and a few other. The shell men were landed in three places and made collections of everything available. I made observations on the abundant bird life but did no collecting as we figure on getting ashore, if not now, later. *Gygis* was present in great number. Shearwaters circled past and boobies and frigatebirds circled overhead. I delighted to see numbers of *Procelsterna.*

About 4:30 we returned to the ship where I partook of small opihis (*Helcioniscus* [= *Cellana*]) raw and found them not unlike clams, very good. They make excellent chowder but in themselves are inedible when cooked as they boil to the consistency of India rubber. We also broke open the curious rock urchins with their strange blunt spines (*Podophora* [=*Colobocentrotus atratus*]) and ate the fat known to the Hawaiian as eggs. Animal was called Buima[?] or Vumma[?]. [The names Wetmore wrote definitely begin with "bu" and "vu" and both end in "a", although the intervening letters are difficult to make out. Perhaps these are intended for *wana*, which is a general term for sea urchins, although the Hawaiian word for this common and distinctive species is *ha'uke'uke*.] Of curious yet agreeable flavor. The view of the great rock cliff in the change and shift of the evening light was wonderful and I admired it greatly. It resembled a huge forbidding Gibraltar with myriads of birds about it.

May 25, Friday

Was busy for most of the day aboard ship. Early in the morning we hove anchor and steamed up past Adams Bay to find the surf pounding heavy in a froth of white on the rocks, so returned again to our anchorage as there was no hope of a landing. During the morning we overhauled the outfit to some extent and the remainder of the time I spent in working on notes on the deck astern. Men on watch were busy with paint and the TANAGER was being spruced up in general for her return.

About three, Commander King put over the surfboat with Dranga and I went for a reconnaissance past the landing. In the lee of the rock we were in a comparative calm area

though white caps showed on either hand. Once past the protection afforded by the point we found a tremendous swell, with waves running 15 to 18 feet high in great masses that broke at times. Gusts of wind drove clouds of spume through the air like rain. We worked along far enough to see the beach where the breakers were churned into a froth of white and then turned and came back. With an ordinary whaleboat we should certainly have been swamped but the surfboat rode easily over the highest waves even where they were breaking and we shipped no water at all. I found on my return that the expedition had given me a tremendous appetite.

May 26, Saturday

At five this morning the wind still continued from the southeast. White caps still continued on either side. At eight we steamed on past Adams Bay where I was able to observe that the sand beach was still bare in spite of the water piled in on it so that it would be available for a camp site. Fuel and water were low so that it was possible to remain here only until Tuesday May 29. From general appearances it appeared probable that the present wind would hold until several days, possibly a week had passed. It was decided best to continue at once to Honolulu as it is necessary for the boat to lay up for a day to clean boilers, which were in bad shape. So we kept directly on over a somewhat rough sea. The reversing engine refuses to work. All hands among the scientists lay about talking, playing cards etc. on the foredeck. I improved much of the day in making up some needed sleep.

In Transit and Honolulu

May 27, Sunday

This morning we passed Kauai, crossed the channel and by noon were coasting in the lee of Oahu. Shortly after five we were off Honolulu when a tug took us in tow and brought us in to the dock. Personal baggage was soon disembarked and we were busy greeting friends. Dickey met us and I was pleased to learn that his films were 90% good.

May 28, Monday

Reno, Schlemmer and I were at the dock at 6:45 a.m. and sorted out our share of the baggage. I shipped 11 boxes of specimens via American Railway Express collect to the Bureau. Through use of Gregory's name we secured passage for Reno leaving on the MATSONIA May 30. At 10:00 I met Dr. Gregory and went with him to Pearl Harbor where we met Commander King and paid our respects to Admiral Simpson. Returned to the museum where I attended to some details and secured mail. Dr. Gregory brought me in to town where I read my mail, did some necessary errands, looked over baggage and worked on notes.

May 29, Tuesday

Worked for nearly an hour on notes and then at a quarter of eight went out to the Bishop Museum where I helped Dr. Ball unpack his bird skins and had Schlemmer sort out my alcoholic specimens. Arranged with Dr. Gregory to have Reno settle his expenses and discussed details of forthcoming parties. Gregory informed me that negatives taken by Lawrence are Bishop Museum property. I told him that if the American Museum, with whom Lawrence has a loose affiliation, desires photos to print in their magazine that they should be secured through the Biological Survey, if they included birds or mammals. Also discussed the matter of publication of reports. Gregory is now in favor of a plan to print

reports in the Bulletin series of the Bishop Museum, numbering them regularly in the usual series but with an additional subtitle "TANAGER Expedition, 1923." The series will include a general account of the islands, history, discovery etc. to include material in the historical archives in Honolulu and then a series of special articles dealing with different groups, of which I am to write the birds. It was agreed that I shall write the bird report for the Bishop Museum series, an account of the seal for the *Journal of Mammalogy*, and one or two general papers for the *National Geographic* or similar publication.

May 30, Wednesday

Reno sailed on the MATSONIA at ten this morning. After he left I returned to the hotel and changed from a large room that he and I have been occupying together to a smaller one. After noon I went to the museum and spent the afternoon in bibliographic work in the library. Called on D. R. Dickey in the evening.

May 31, Thursday

[Went with Schlemmer on a hike up the Palolo Valley east of Honolulu. Mentions the vegetation and birds seen, the only native species being the Elepaio *Chasiempis* and night-heron *Nycticorax*.]

[June 1-3 in Honolulu]

June 4, Sunday

Labelled and cataloged photographic negatives all forenoon. Spent the afternoon with Max Schlemmer and secured much valuable information regarding Laysan Island.

[June 4-7 in Honolulu]

June 8, Friday

Had an appointment at 9:00 a.m. with Mr. T. Thrum but was unable to secure a copy of the *Hawaiian Almanac* that I desired. At 2:00 p.m. had an appointment with Commander King and went on board the TANAGER which had just come around from Pearl Harbor.

June 9, Saturday

This morning I prepared baggage and sent it with other supplies to the ship. Worked on expense accounts and correspondence until four and then went aboard. The TANAGER sailed at five with quite a crowd on the dock to see us out. A fine clear day with light northeast wind. I had a fine view of the island of Oahu as we came out. We ranged cots along the forward deck and all who could slept there. A few turned in below. [Personnel list omitted---see itinerary.]

NIHOA ISLAND (Camped)

June 10, Sunday

A fairly smooth sea today with a following wind. Very few birds about. Only one Black-footed Albatross at the stern. Occasional tropicbirds or boobies passed and a good

many Wedge-tailed Shearwaters seen. Busy in afternoon getting outfit on deck to make landing if practicable on Nihoa. The island was sighted about two p.m. and we were at anchor a half mile off shore at the entrance of Adams Bay at 4:15.

The surfboat was lowered and Commander King, Montagu Cooke, and I, with Anderson, went in at once. Surf was running but the wind was northeast which gave a slight lee as the bay opens southeast. The sand beach at the western end of the bay was impracticable as heavy swells broke on it every two or three minutes. On the eastern side of the small western bight is what we have called Wilder's landing after G. P. Wilder. Here there is an irregular rock six feet across on which I jumped as the swells lifted the boat in. Landing here seemed practicable and I climbed along to look for a camp site while Cooke came ashore. Camp goods and supplies came off immediately. Schlemmer perched on the rock while I stood in a hollow behind it with George Higgs the cook. Bryan, Cooke, Thaanum and Grant were ranged up the shelving rock slope behind. Higgs and I held a rope in case of need as every minute or two heavy surf swept in drenching me at times to my arm pits. Small articles were tossed from the boats to Schlemmer who passed them back. Water breakers and some cases of canned goods were tied to ropes and thrown overboard so that we could drag them ashore. A bunch of tent poles struck me in the leg and nearly knocked me down. One surf washed George down against me, nearly precipitating me in the sea. The sugar fell in but was rescued, a few sacks of food were lost overboard but in general the landing was made without damage. Once a heavy surf caught the whaleboat and swept it full length up onto the rock shelf on which we were landing but luckily by strenuous backing it slid out again without catching as the wave receded.

After the first two loads it became dark so that the ship's search light was turned on and we worked until nine by this light. Our equipment was light but much time was required to maneuver the boat while two or three bundles were thrown ashore and then the boat would be swept away by the waves and have to be worked back again. In the bright light of the searchlight the landing rock and the adjacent water was clearly outlined and with the boiling surf and black background made a wonderful sight. At nine the tide had raised so that we had to stop. I asked that the light be kept on for an hour while we stowed the goods and made camp. A little overhanging rock shelf sixty feet above the water offered a little protection and a ledge in front of it gave just room for our cots with our heads under the shelter and our feet projecting in the open. With everything secure we lay for a few minutes and admired the white froth on the waves, the huge black headlands and the forms of flying birds, and then the light was turned out and we fell asleep.

June 11, Monday

Kamehameha day, a Hawaiian holiday and a day appropriate to Nihoa since the third king of that name came here at times to some sort of a summer camp. The wind had freshened somewhat but the rest of our equipment was landed without incident except that we were all drenched more or less in the process. We landed as little as possible here, taking care only to get water and food stuffs. We pitched one tent on a rock shelf in a sheltered corner by tying the guy ropes to convenient projecting corners of stone. Food supplies were carried here. Our scanty personal equipment was stowed under little rock ledges and I put up a tent fly as a shelter for skinning etc., and all hands turned eagerly to exploration of our new ground.

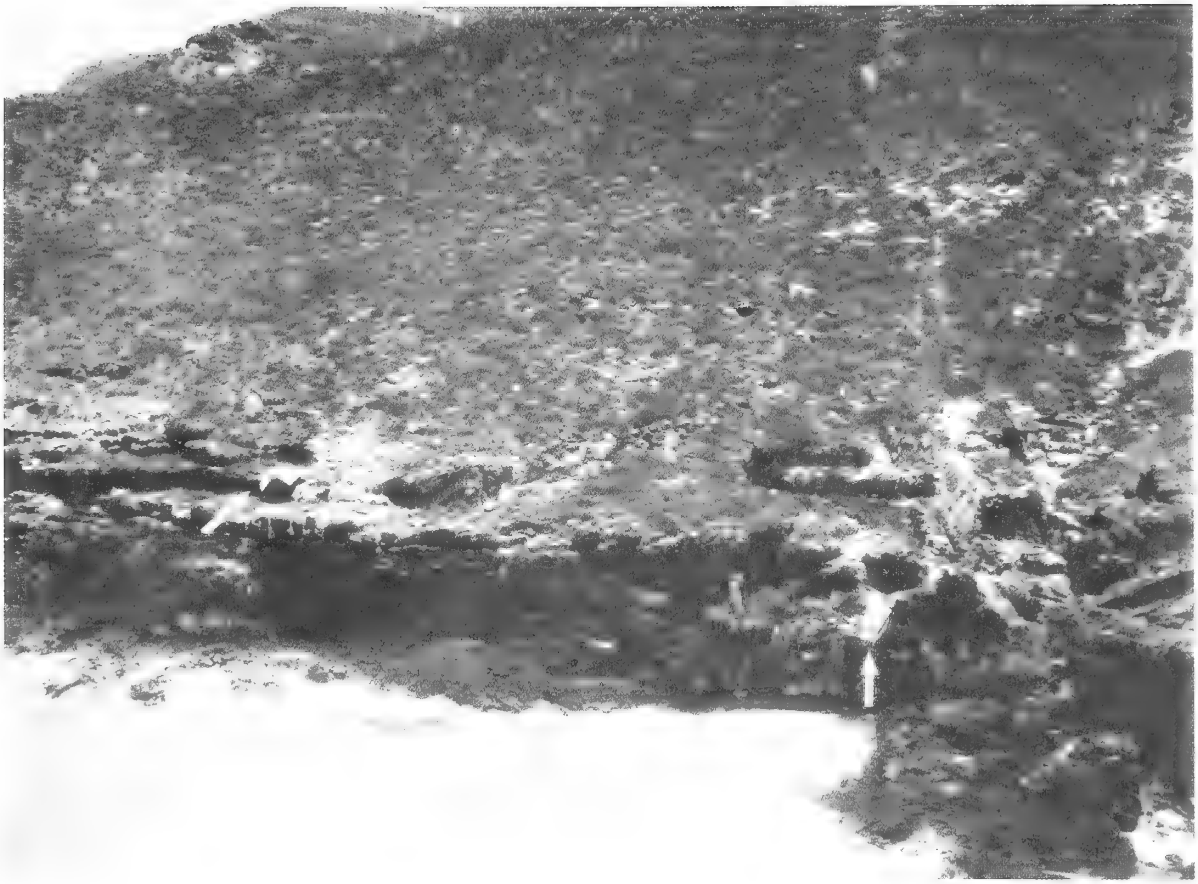

Figure 19. Our camp site above Adams Bay, Nihoa Island. June 12, 1923. [Arrows indicate tents.]

Nihoa Island is about 3/4 mile long by roughly 1/4 mile wide. Adams Bay, the only break in the great precipices that form its side lies at the center of the island and opens to the south and southeast. The bay consists of three bights. Our landing was made at the inner point on the easterly side of the middle one and our camp is located at the northeast corner of this same bight. The hill slopes rise steeply inland from the bay but climbing though arduous is not particularly difficult. Three main valleys divided by high sharp ridges drain into the three bights and small secondary valleys in addition may be traced in the two eastern sections. The rock of the island is entirely volcanic with the dikes examined previously in the western face exposed in many places. The steep slopes have considerable soil though it is shallow and contains many rocks. Vegetation is abundant.

A woody-stemmed shrub, a goose-foot with leaves and inflorescences of a *Chenopodium*, is most abundant and covers great areas. It grows from one to three feet high in the arroyo reaching 4-5 feet in sheltered corners. What looks like a *Euphorbia* is found on the higher slopes and bunch grass occurs on the sides of some of the steep ridges. There is a small amount of a woody-stemmed legume, a small lily[2], a pigweed and other plants. In the eastern and western valleys are small groves of the Nihoa Palm

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[2]Lilies are an extremely minor component of the flora of the main Hawaiian islands and no lily has ever been reported from Nihoa or any of the other islands of the northwestern chain. Perhaps Wetmore was seeing sprouting seeds of the *Pritchardia* palm.

(*Pritchardia*) growing from six to 30 feet in height. This palm has a swollen base, a slender trunk that, except where twisted by wind, is straight and an expanded head with broad fans and an abundant supply of round seeds as large as a hickory nut. These trees grow in small clumps on the sides of the slopes in several spots high up or in small level spaces in the bottoms of the valleys. There are probably 200 or more of them. I noted many sprouting seeds in the soil.

My first visit was made to the eastern valley. We climbed up above camp and then along the side hills until we were able to enter the side of the valley. The Nihoa Finch had greeted us familiarly in first landing and I was greatly pleased to find them abundant. A *Tatare* was a welcome addition to the land bird fauna and will undoubtedly prove new [It was---see species accounts]. In the eastern valley I found water of poor quality at several points. It was flavored strongly with guano but would serve for consumption in a pinch. Several small pools were noted in the valley and one trickle of a few drops was located in a small cave high above.

Gray-backed Terns were nesting abundantly over the slopes with many noddies and Sooty Terns. Red-footed Boobies were common, with occasional groups of frigatebirds, Wedge-tailed Shearwaters and Bulwer's Petrels were scattered everywhere. With an occasional Blue-faced or Common Booby these made up the bird-life of the island. I collected a small series of finches, a few millerbirds, and some other things. In the old village site in the eastern valley I picked up a fine stone calabash entire and part of another. The afternoon was busied at camp. Clear and hot today. At five p.m. the sun sank behind the western hill and it became cooler at once. Our location for work in the afternoon is very comfortable. Insects are abundant, among them blowflies which do not occasion much trouble.

June 12, Tuesday

The surf booms and surges against the rock cliffs below our beds all night, occasionally waves dashing spray high in the rocks. This is carried away from us, however, and though it rises to the level of the cook tent occasions no trouble. The heavy impact of the larger waves in a narrow channel below us wakens me occasionally at night and I never tire of watching the dash and foam of the waves on the rock ledges. This morning we worked along the ledges to the sand beach in the eastern bay where I collected a number of Necker Island Terns. This sand beach is about a hundred yards long and slopes gradually. Waves dash on it heavily so that it makes a bad landing, while with heavy surf it is swept almost to the base of the rock. It is fortunate that chance directed us to a more central place for our quarters from which we have easier access to all parts of the island. Some logs of driftwood have been cast on the beach and there is a cave into which waves enter at the outer end. From here we climbed up into the western valley, examined the palm groves and continued on to the base of the pecker rock Ka-Ule-Na-Na-Hoa. The western face breaks sheer in the huge pali examined from the ship. Climbing was slow work through not particularly difficult. At noon we returned with a large number of birds so that we were occupied steadily until dark in caring for them. Opposite our camp is a small cave merely large enough for shelter for one man that has been occupied by a Japanese within 18 months. Two old wooden buckets, remains of a bed of grass, the inevitable bit of bamboo, and a bottle or two containing soya sauce were evidences of the nationality of the occupant. Above were remains of birds used as food. The wind shifted southeast today pounding a heavy swell directly into our bay. Landing would not have been possible. Occasional clouds passed today and two or three times little showers fell but not in great quantity.

June 13, Wednesday

We rise at daybreak here. I waken as the stars begin to pale in the lightening sky and lie for a few minutes until a rosy hue suffuses the clouds, while the tremendous waves boom and pound below, seeming in their overpowering strength to almost shake the huge rock that forms our haven. Pools left by the tide on the rock shelves below the cliffs form convenient receptacles for our rather casual ablutions and no one seems to mind a dash of water from an occasional breaker. Breakfast comes at six, giving a long day that is busily occupied.

Cooke and Thaanum are greatly elated at their takes among the land shells. I have had to curb Bryan's enthusiasm over the insects as he came in last night completely bushed, and Grant is collecting fishes in the pools and is taking other invertebrates. Today he found other stone dishes in the village site in the eastern valley.

Figure 20. Eric Schlemmer in our work quarters on Nihoa Island. June 11, 1923.

A few skins remained from yesterday so that it was eight before we left camp and climbed to the summit of the central valley. From there I worked along the edge of the precipice to the eastern valley, descended through the ancient village and then returned to camp at noon. The view along the northern cliffs is one of the most wonderful in my experience. The huge black wall descends sheer to the water below rising in jagged peaks that form fantastic outlines. Below may be made out shallow points on the ocean bottoms. Terns, frigatebirds and shearwaters swing back and forth overhead. All photographs have

to be taken at 1/100 of a second, otherwise the movement of the birds would blur and spoil the sky line. At one point the edge of the cliff receded somewhat offering a steep slope down which we climbed and collected a few White Terns. The cliff dropped sheer for 600 feet below us. Finches fluttered above us and evidence of their work on petrel's, shearwater and tern eggs were evident all about. The number of eggs that they destroy is enormous.

The day was clear in the main, though drifting masses of cloud frequently obscured the sun. One or two light showers fell. Heavy surf from the southeast continued to pound into our bay so that boat work would be impracticable. The TANAGER left Monday at two p.m. to convey a second party to Necker. I have with me here Schlemmer, Cooke, Grant, Thaanum and Bryan, with George Higgs as cook.

June 14, Thursday

The wind today came from east-southeast rolling a heavy surf into Adams bay. Fleecy white clouds drove across the sky but still left sufficient sun for photography. This day I devoted to exploration of the eastern portion of the central gulch. Along its lower portion were several small pools of water strong with guano washed from the rocks above, but still fit for drinking if boiled and filtered. Finches swarmed in the bushes about these and I saw a good many millerbirds. Gray-backed and Sooty Terns were scattered along the slopes, noddies nested on the rock ledges and I passed occasional groups of Red-footed Boobies and frigatebirds on their nests. Wedge-tailed Shearwaters were everywhere underfoot and I found numerous Bulwer's Petrels. Red-tailed Tropicbirds scolded at us from little caverns. We continued the ascent to the summit of Millers Peak which is given as 903 feet feet above the sea. The steep slopes were covered with the woody stemmed *Chenopodium* with areas of bunch grass below the summit. Occasional lilies [see preceding footnote] and clumps of *Euphorbia* were seen.

The peak rose abruptly in a pinnacle of rock that was sheer on the north and west but that could be scaled easily from the south. Below the peak on the west was a huge cleft that separated it from a point to the northwest nearly as high. The cleft descended steeply between two high cliffs its stony slopes covered with nesting noddies, boobies and Sooty Terns, while Love Birds hovered on the shelves above. After a steep pitch of 400 feet it dropped over a precipice into the sea. A winding ridge led out to the second peak from a small flat on the very summit of the island. It was astonishing to find this flat occupied by a small colony of Black-footed Albatross. Accompanying them were many Blue-faced and Red-footed Boobies.

The summits of the two peaks were occupied by cairns of rocks built up in rectangular form to make platforms 6 to 8 feet square with level surfaces strewn with fragments of coral. These may have served as watch towers or may have been used for beacon lights to guide belated fishermen to the island or---most entertaining thought of all---they may have served as lights for the guidance of pilgrims returning from homage at the shrines of Necker many miles to the westward. From these high points I had a wonderful view of the island. The great triangular hill at the eastern end was visible as a huge majestic pile, sheer to the north and sloping steeply to the south. Below the irregular hill slopes was the small indentation of Adams Bay with the projecting peninsula on its western side. To the west and north the rock walls dropped sheer for hundreds of feet to a sea that appeared broken merely by slight ripples from this altitude until I noted the white froth of the huge breakers thrown up in impotent force against the bases of broad precipices below me. Light patches indicating shoals were clearly visible and alternating with shifting purple

cloud shadow gave the water plain a pleasant, colorful, varied mosaic that was beautiful in its soft shades and restful colors. On all sides away from the horizon [= island] the great ocean extended to the horizon, obscured by a haze in the distance that may betoken a storm. The view reminded me of the tremendous plains of the Argentine seen from some high eminence on an eastern escarpment of the Andes. Birds hovered in abundance about us, sweeping past continually. So abundant were they that they actually interfered with photography as I had to make all exposures rapid snapshots.

The return to camp down the steep slopes was rapid and we were soon in the sun and I noticed that other members of the party were affected as shown by flushed faces. Grant was ill this afternoon from indigestion due to eating canned tomatoes without cooking, and exposure to the sun. At five the sun sank below the western hill and relief from the heat was immediate. I was busy with skins all the afternoon. At six took a needed bath in pot holes cut in the rock platform at the base of the cliffs. We retire at dark and Cooke and I, with adjacent cots, usually talk for an hour before falling asleep. Tonight I read a verse or two of Omar and then turned in. The Southern Cross was plainly visible in the clear sky in the southern horizon and east of it the bright point of Alpha Centaurii. Birds passed continually overhead and I awoke once in the night to find a Wedge-tailed Shearwater resting on my knee.

June 15, Friday

Awoke this morning to find the air filled with circling birds and watched a rosy glow from the rising sun suffuse the higher clouds. Wind easterly today but waves running very high so that they smash heavily on the rock shelf below our little camp. One or two slight rain squalls passed during the day. I worked along the top of the cliffs from camp to the eastern valley. There is a shelf 50 to 100 feet [wide?] that extends above the water line from the sea itself to the base of the cliffs. This is washed frequently by the larger waves. Above this the cliffs rise from 60 to 125 feet with a series of slanting ledges above, along which one may work without great difficulty.

The Necker Island Tern was common here and I collected a small series. Gray-backed Terns nested in little groups, Wedge-tailed Shearwaters and Bulwer's Petrels were breeding everywhere and I located a few small colonies of *Sula leucogastra*. From here we climbed up the eastern valley as far as the lower cave. Bushes about little water holes were filled with finches whose actual number was unsuspected until one tramped out the brush. An occasional millerbird peered out but I looked in vain for the rail. [No species of rail has ever been reported from Nihoa, Wetmore's statement presumably being based on an assumption that a species similar to the Laysan Rail might be expected on Nihoa as well as on Laysan. The possibility that there was an endemic rail on Nihoa that was exterminated prehistorically has also been raised (Olson and Ziegler, 1995).]

The palms are now filled with nuts, the pericarp of which is eaten by the finches. A number of the trees held nests of the Red-footed Boobies. The hold of these trees on the island seems somewhat precarious. They grow in struggling groups amid the rough stones of a thin soil, confined by necessities of the dry season to the drainage valleys or the slopes just above, where they are subject to the wash of torrential rain. The tallest reach an altitude of 40 feet but the majority are not more than 20 or 25 feet high. Though a few dead ones were seen, the majority seemed thrifty. The soil beneath the trees is strewn with fronds and the husks that cover the fruiting heads. It was pleasant to rest for a few minutes in the shade where I could look out through the close-set stems to the ocean.

Several pools of water in the little valley were strong with guano. At one side of a small cave was a tiny pool of perfectly clear water and I was astonished to find this sour and bitter with mineral matter, wholly unpalatable and without special treatment unsafe to drink. The heat on the hill slope at noon is considerable and I was glad to reach camp where I had the shelter of a tent fly. The wind increased somewhat during the afternoon and the heat in camp was not uncomfortable. Cooke and Thaanum returned from the eastern slope of the eastern valley with two stone calabashes that nested one within another, a broken calabash and bit of wood three feet long with two or three perforations in it found in a cave at an altitude of about 500 feet.

June 16, Saturday

Following is my census of the bird life of Nihoa [Seabird data removed to Table 5. *Anous minutus* was inadvertently omitted from Wetmore's list. He recorded only "small numbers" of them in his species accounts.]:

Telespyza ultima	800 individuals
Tatare	100 individuals

This morning as I was busy with packing I saw the large figure 5 painted on the bow of the TANAGER appear beyond the western promontory that bounds Adams Bay and the boat slowly forged into view. There was a heavy swell off the entrance of the bay and the ship rolled so that the surfboat could not be put over the side. She forged slowly along and then went back in the lee of the island to reappear in half an hour towing the surfboat behind. The small boat was towed to a proper point and then cast off and came in. The surf was breaking heavily but we landed Judd, Palmer, Caum and Cartwright and their gear without great difficulty. I climbed out then on the landing rock to talk to Commander King. A large blind roller came in silently from behind and dumped half a ton of water on me unawares, knocking me off the rock. I turned out as I fell and went out with the wash and then swam up through the foamy water and came out to the boat where I climbed aboard and we finished our conversation; hat and glasses still in place. Finished packing and got off the last load by noon after much maneuvering and some skillful boat work to avoid a spill. Was relieved to get camera, notes, film and specimens aboard ship dry. We rowed around the point and embarked in the lee. A small sampan was at anchor here. At 2 p.m. we left for Necker. As we passed out we steamed around the island giving a fine view of the marvellous cliffs.

Nihoa at one time supported a considerable human population considering its size. In the eastern valley are 30 or 40 platforms a part of which served for houses and a part apparently for other purposes. These have been built up of stones often as heavy as a man can lift from three to fifteen feet high on the front depending upon the steepness of the slopes on which they are placed. The front and side walls are perpendicular with the stones nicely fitted together leaving only comparatively small chinks between. Earth filled in above gives a level platform. In some, two stones two feet apart at one corner against the hill seem to mark the doorway of a grass hut. In some are stones three to five inches in diameter and 18 to 24 inches long set upright, usually four together in a quadrangle. These may have served to support stone bowls or may have been the supports of tables. On one of these platforms, perhaps the site of a heiau, there were two upright stones a foot across the face and four inches wide, two feet tall standing six inches apart. The platforms range from 4 x 6 feet to 10 x 15 feet in area. Some stand out boldly, looking out across the valley toward the sea. Certain hill slopes here have been terraced with stone work for considerable areas to make benches four feet wide and often many feet wide that seem to

have been used for cultivation, probably of sweet potatoes. Along the two main ridges dividing the three main valleys are little stone enclosures that may have been heiaus or may have served as watch towers. Small platforms over the cliffs above the sea may have served as lookout stations for those who watched for fish. Grass huts on stone platforms overlooking the valley toward the sea, others with closed walls guarding temple secrets, terraced fields of sweet potato or taro with stalwart Hawaiians climbing up and down the slopes, with here and there a lookout or a commanding point on watch for schools of fish, canoes drawn on the rock ledges below, where a dozen men might seize them and, waiting a favorable instant, launch them in the surf. Such is the picture we may bring before the mind of ancient life in these valleys.

Though some of these peoples may have been transient here, the terraces for cultivation would indicate a considerable period of residence for some at least. The fair preservation of the walls would indicate that the valleys have been occupied within from 300 to 400 years. Water must have been a problem met perhaps by some method of impounding the winter rains in the lower courses of the drainage valleys. Bird life in those days must have been confined to the palis save for petrel and terns that nested in the cliffs and the millerbird that hopped about in the clumps of bushes and the finches that came in friendly fashion about the houses. Now grass huts have disappeared and platforms and terraces alike are masked by heavy growths of low bushes. The sea birds have come in to their own and nest in every available space over the rocky slopes.

At the base of a high platform to the west of the main clump of palms in the eastern valley I found a stone bowl about six inches wide and twelve inches high. Grant found two others near here, one 10 inches high by an equal breadth and a flat stone pan that may have served as an evaporator for salt. Cooke and Thaanum discovered three bowls in a cave at an elevation of 500 feet on the eastern side of the most eastern valley. Two of the bowls were of the high type and one nested within another. With these was a piece of perforated wood, from its form apparently the yoke of a boat rudder. [The archaeology of Nihoa is treated in Emory (1928) and Cleghorn (1988).]

NECKER ISLAND (Camped)

June 17, Sunday

At six this morning Necker was near at hand, appearing as a square block of rock rising from the ocean. At seven we were at anchor a half mile away and soon after the first load started ashore. Landing was made at a rock ledge on the west of the northern peninsula where there was a high ledge at the base of the cliff with a depth of 7 or 8 fathoms of water. The peninsula offers a lee from the north and east and though there is much rise and fall of surf the boat rides free as the rock face is sheer. Landing was made without incident. Found A. L. C. Atkinson in camp here with Anderson in a small basin at high tide level. Moved camp to the rock ledge above, where things were more secure. The cliff rises steeply here about, with a series of ledges, some with a slight overhang that offers shelter. Climbing is steep but not difficult. The cook tent was located in a sheltered corner 50 feet above the waves and cots for sleeping scattered over small ledges from 20 to 40 feet higher wherever there was room. My own perch was one of the highest of all. Day occupied in establishing camp and bringing note books to date. The TANAGER left at four to convey Dr. Cooke to Waimea.

Figure 21. The landing on Necker Island. June 17, 1923. [Wetmore is in skivvies holding what is probably a green turtle (*Chelonia*) over his head. There is no mention of this in his journal, nor is there any part of a specimen of turtle from Necker in the Smithsonian collections.]

June 18, Monday

This morning I climbed the hill above camp and worked over it during the forenoon. The "trail" led up a cliff with steeply slanting ledges with many overhanging rocks. Care is necessary in climbing as the stone is often decomposed so that comparatively large masses sometimes break away with the weight of a man. Sooty and Gray-backed Terns were everywhere, frigatebirds were common and on the summit were many Laysan Albatross, Blue-faced and Red-footed Boobies.

There was comparatively little soil on the knoll and plant life was confined to a *Portulaca* and a shrubby legume. Spiders abound, there are *Dermestes* and other beetles, moths, lycaenid butterflies but apparently no blow flies. The summit of the hill was given over to large platforms of old heiaus. Flat spaces had been made by building up a foot or two where necessary and in some cases were partly enclosed by low walls. The largest was 15 x 30 feet. Along the northern and western borders blocks of stones two to four feet high, a foot to two feet wide, and six inches through, were stood on end at distances of from two to four feet. In general these blocks were rectangular. One, two or more were placed in the center or at some other point within the enclosure. One or two were of rounded form and were water-worn apparently brought up from the beach.

Figure 22. Camp on the cliffs of Necker Island. June 19, 1923.

At noon I returned to camp and spent the afternoon in skinning. Schlemmer and I skinned 4 albatrosses and 2 frigatebirds on the the hill this morning to avoid the labor of bringing the entire birds to camp. This morning I awoke at the first sign of day and found a heavy bank of clouds at the horizon. The rising sun's rays tinged these with rose and as if at a signal the terns came rushing out overhead in a great flock. From my cot, which is placed at the very edge of a rock platform, I have an uninterrupted view and though the other rock ledges lie below, I cannot see them and am 80 or 90 feet from the level of the sea. We have named this camp "Kukai Manu" for obvious reasons since asleep or awake we are sprayed at intervals with whitewash or heavier material from the hosts of terns, boobies and frigatebirds that circle overhead. [Wetmore slightly misspelled the Hawaiian; *kukae* = excrement and *manu* = bird].

June 19, Tuesday

Today I worked farther out along the slopes of the island finding them rough and rocky with slight soil and little vegetation. Colonies of Red-footed Boobies and frigatebirds occur wherever there are any shrubs. Blue-faced Boobies and two species of albatross are distributed over the higher slopes. Sooty and Gray-backed Terns are everywhere. The summits of the hills are occupied by heiaus of the type previously described: the erect stones face indifferently on all sides but nearly always toward the open sea. Clambering about over the rough rock is very destructive to the shoes. A pair that I

A pair that I had hobnailed for this special purpose are about played out and will hardly last until the TANAGER returns. Much care is necessary in climbing as on the upper slopes the black volcanic rock is badly decomposed so that large fragments break off under the weight of a man. The relative fearlessness of birds here is interesting. Noddies are alert and fly before danger is near. Gray-backed and Sooty Terns are more fearless but still are difficult to catch. Albatross, frigatebirds and boobies are indifferent to our presence. The hosts of terns are the dominant feature of the bird life. Wedge-tailed Shearwaters are common but not abundant. Bulwer's Petrels are in evidence only at night, when they circle about our camp. The sides of the island are more or less sheer and to visit the various rock platforms at the water's edge requires considerable labor in climbing about. The wind today was directly east. It is very warm during the day but nights are cool and pleasant, with a cool breeze that makes a blanket comfortable. A small shower of rain fell today. Several have passed the island but this is the first one that has touched it.

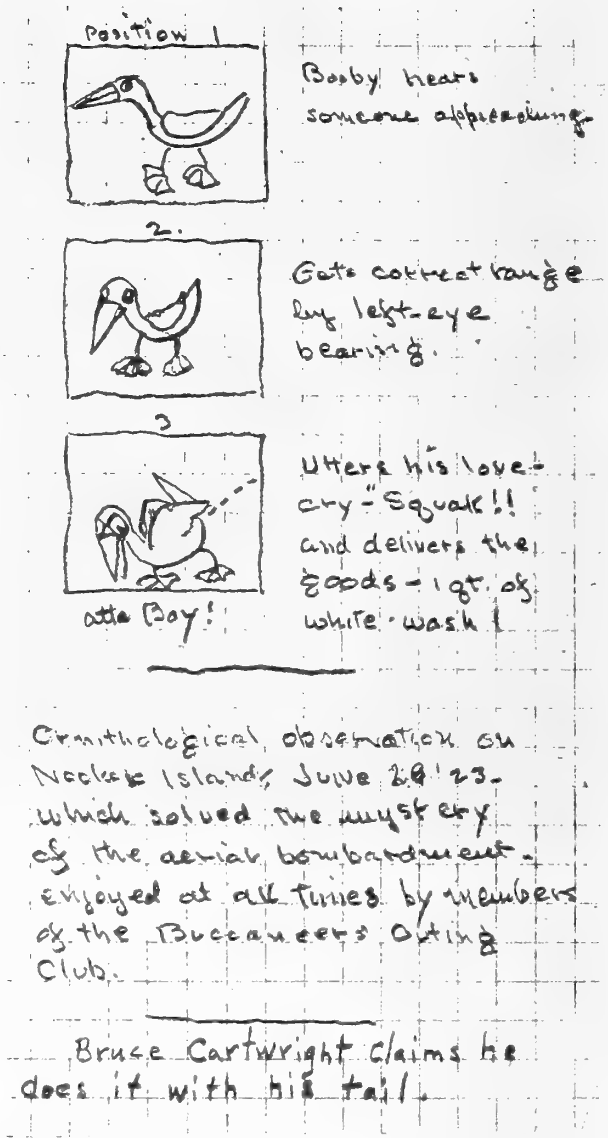

Figure 23. Humorous sketches from Wetmore's journal inspired by the rain of booby-derived guano upon the expedition members on Necker Island. The author/artist was not identified, but the handwriting is not Wetmore's.

June 20, Wednesday

Clear and hot today. Worked out during the forenoon to the other end of the island, climbed down to the little rock flat at the water's edge where I collected a Golden Plover and a turnstone and then returned to camp.

Necker Island is a huge rock that rises in 5 more or less well defined peaks connected by low ridges, with a 6th point at the northwest set off and almost separated from the main mass. A rock lies off the southern end of the island. The slopes are steep and in some places precipitous though in most parts by careful choice of routes it is practicable to climb up or down along small ledges. The rock is decomposed and care is required in choice of hand and foot holds. Soil is scant and there is little vegetation. Slopes everywhere are covered with the excrement of birds but not in sufficient volume to make it profitable to gather guano. The peaks mentioned lie in one long somewhat curving

make it profitable to gather guano. The peaks mentioned lie in one long somewhat curving ridge that at the north end partly encloses a small bay. This bay at the present season is on the weather side and landing is made on the western side of the northern end. There there is a broad rock ledge and at the western end, where this ledge joins the main cliff, boats may be laid broadside-to even in heavy swells when by fending off with boat hooks they will ride clear, rising with the swells and dropping as the water recedes, carried out by the back wash. Below at this point the water is deep and there are no dangers.

There are numerous clefts and caverns on the sides of the hills but none are extensive. The stone platforms on the summits of the hills are the most interesting feature of the island. Today I saw two that were at least 6 feet long by 25 broad. In the ordinary form these are perfect rectangles with a platform of stones a foot high and three or four feet wide along one of the long sides. The larger and more prominent upright stones stand at the back of this. Other upright stones may be ranged at three or two of the other sides. To my mind these are all temples. I see no indication that Necker has been regularly inhabited and believe that people came here for worship at certain seasons of the year. Four or five turtles haul out on the rocks of the little bay in early morning. I see others from the cliffs swimming in the water. Sharks and other fishes are common also.

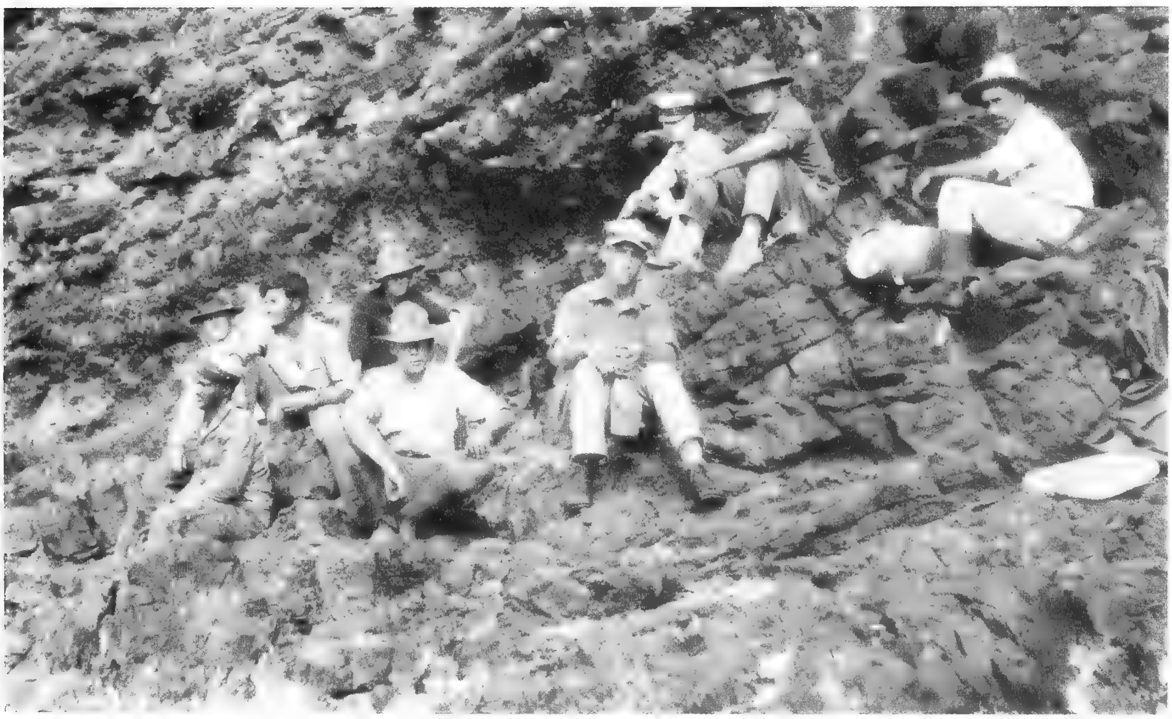

Figure 24. Left to right E. H. Bryan, Geo. Higgs, W. G. Anderson, E. Caum, H. Palmer, E. Schlemmer, Red Dofflemeier, B. Cartwright, C. Judd. Necker Island.

June 21, Thursday

The TANAGER arrived at 6:30 this morning and Commander King reported no difficulty in disembarking the party at Nihoa. Calm sea today with an easterly wind. Our camp was rapidly dismantled and by 8:30 our gear was all aboard. The last boat went off to the ship at 10:15. The afternoon was occupied in making soundings to the southeast of Necker in search for a shoal which is charted but which seems to be non-existent.

Anderson today climbed to a cave on Necker and dug out a very curious implement whose use is problematical. It is T-shaped in form with a hook at one end. King suggests that it was used in repairing nets. It was of rather coarse grained stone but was smoothly worked.

Figure 25. Sketch of a stone implement from Necker Island, Wetmore's journal. [Emory (1928:96) discussed this object and illustrated it, likening it to a New Zealand bird snare perch normally made of wood, an interpretation that strikes me as rather fanciful.]

French Frigate Shoals

June 22, Friday

At eight this morning we were in sight of French Frigate Shoals and went around the northern end into the lee on the south, passing near the rock and continuing on to what is shown as the main island. We went over to this at eleven and I was greatly disappointed to find it much smaller than is indicated on the charts. It is elongate, slightly curving in shape and, according to an accurate map made by Judd, 1890 feet long by 400 feet wide at the widest part. On the chart it is shown as over a mile long. The reef extended along the southern side so that any boat was forced to detour through a break to get in. Anderson and I went in however through a break where the water was shallow in a small skiff. We landed camp equipment and had a camp up in short order. The surface of the island is coarse coral sand with many fragments of large shells. It is filled with shearwater holes and tents were ranged around more or less at random where little open spaces were available.

The party here consists of Judd, Thaanum, Grant, Anderson, Schlemmer, Wetmore and George Higgs, cook. Palmer, Bryan, Caum and Cartwright work from aboard ship. At 1:30 Commander King came ashore again in the motorboat and I accompanied him during the afternoon while he made some soundings. We visited a small sand spit a short distance east of ~~King~~ East Island[3] as we have called the island on which camp is located and found it an elongate island 60 yards long by 10 wide, merely a ridge of sand rising 5 feet above the water and evidently swept. A few noddies rested on one end and I killed one Hawaiian Tern from a little flock that swept past. We continued from here northeast nearly to the end of the reef and then turned back and ran across to another sandspit 100 yards in diameter rising 8 to 10 feet above the sea. The higher portion was covered with plants of four species---a grass, *Tribulus*, *Portulaca* and a fleshy leaved spreading plant. There was the boom from the mast of an old schooner here and evidences of a camp some years ago. Returned from here to camp. There are many coral heads just awash in the lagoon here and shoal patches all through. On the average the water here ran from 4 to 7 fathoms.

Anderson tells me that formerly on Fanning Island the Gilbert Island laborers in making their labor contract specified that each man was to receive 2 birds (i.e. boobies) per day as part of his ration. The birds (*S. piscator*) were captured at night from their roosts in

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[3]Wetmore evidently named this island after Commander King of the TANAGER, as it appears in several places in his notes and catalogs. King either declined the honor or it was decided that the earlier name East Island had priority, as the latter was substituted and "King" was struck through in several places in the journal, though not everywhere, and the correction was not made at all in Wetmore's species accounts.

the coconuts and that care was taken not to disturb the nesting birds. The practice has now been discontinued. He tells me too that ducks come in large numbers from October to January to Fanning and Washington, northern migrants that appear each year. At one time he took a young frigatebird and reared it by hand. When they crossed from Fanning to Washington they took the bird with them, and sent it back with a message. It was home in a few hours. He knows of no seal in those parts nor did he find any on Johnston. Captain Ingham is certain that he saw a seal in one of the caves on Nihoa.

June 23, Saturday

Today was occupied in a survey of ~~King~~ East Island as we have named the islet on which we are camped. The island rises from 8 to 10 feet above sea level and supports seven species of plants [Christopherson and Caum (1931) mention only 6 species collected by the TANAGER expedition at French Frigate]. Vegetation is not continuous over the surface but grows in mats with little gaps between. The beach is narrow and rather steep. In addition about 20 *Sula piscator* and half a dozen *Fregata* roost here at night. *Gygis* and *Sterna fuscata* pass in small numbers and curlew, turnstone and Golden Plover range in small numbers on the beaches.

At one point there is remains of an old tripod of timbers and below it a three inch iron pipe driven in the sand with a boxing of wood around it. Not far away are two portions of masonry of large fire-bricks three feet square by 6 feet long. The bricks are old style flat bricks and the masonry is apparently ancient. The two masses now lie on the beach. The use of these is problematical.

The island has been much larger but has been cut away by storms. It is hot here but not uncomfortable. A gentle tradewind blows steadily and one does not feel the need of shade. Shearwater, Blue-faced Boobies, noddies, and young albatross are all about our camp and furnish an endless source of interest. Shearwaters here are still mating and at nightfall gather in large numbers to moan all through the night. Occasional light showers of rain fall.

I unpacked the collection made at Necker and Nihoa, gave them a further drying, and then reboxed them for shipment. At dark went out for petrels but found none. The bright moon made the flashlight ineffective as birds were able to see me. Took two flashlight pictures of shearwaters.

Judd has planted the following on King Island [sic, uncorrected].

50 cuttings of *Hibiscus tiliaceus* (Hau)
8 sprouted coconuts
seed of *Haematoxylon campechianum* logwood
Thespesia populnea milo
Casuarina equisetifolia ironwood
Pritchardia pacifica Fiji fan palm
Pritchardia gaudichaudii Hawaiian lelo palm
Livistonia [sic] *australis* Australian fan palm
Calophyllum enophyllum Hawaiian kamani

June 24, Sunday

Awoke this morning at five and completed my notes to date. A clear day with light northeast wind. At eight Commander King came off in the motorboat and we made a cruise to the eastern sand islands in the lagoon, of which there were two. The first and most northern of these was a curving sand spit 1/3 of mile long and from five to 150 feet wide. At the widest point there was a small area 10 feet above sea level and here were a few scattered plants of *Portulaca*. There was no other vegetation on the island. From this wider point a long curving spit ran out to the north. Three or four turtles were seen, one with a front flipper missing. The beach was of coarse shell and corals. Very few shells were found. About 10 pairs of *Sula cyanops* bred here and now had well grown young.

Figure 26. Commander S. W. King directing a landing at a small sand spit north of East Island, French Frigate Shoals.

The island was given its name [Gin Island] from fond memories recalled by an empty Gordon gin bottle that we found cast up by the waves. Little Gin Island which lay about 400 yards south was approximately 300 yards long by 100 yards wide in its main part and 10 feet high at the highest point. A slight depression at the summit, 50 yards across was grown with grass, *Portulaca* and another plant and was occupied by a colony of birds. Toward the north a sand [spit?---word omitted] long and narrow extended for 250 yards. At one end of the island we found a nest of turtle's eggs with developing embryos.

From here we returned to the ship for lunch and then King and I returned to camp. Broke camp and loaded the outfit in the motorboat in half an hour. The other members of the party returned to the ship, which moved down to the westward and King and I continued in the motorboat through the lagoon to Round Island and then on to two small

islands to the westward. We examined these in passing and then turned down to the largest of the western islands.

The lagoon on the average in this western part ran from 3 to 5 fathoms but was broken by many coral reefs and heads over which there was often only 6 or 8 feet of water and which in some cases were mainly awash. The water was calm with only a slight ripple on its surface. At the western island we had some difficulty in getting through a small offshore reef and finally went aground on sandy bottom at the northern end of the island. To lighten the boat all hands carried most of the camp equipment ashore to a low point until the motorboat was floated. Fortunately we had a skiff with us and in three loads with this the camp gear was transported to the central portion of the island which was higher. Schlemmer, Anderson and I, with three sailors labored at this and had the outfit transported by the time the surfboat came in from the ship. The cook tent was put up and when the others arrived the remaining tents were put in place and the camp established in short order.

The boats returned to the TANAGER about 6:20 and a few minutes later George announced supper, two skillets filled with fried mullet and a pot of beans on the side. Camp was located on a stretch of fine coral sand adjoining the vegetation on the southern end of the island. After our meal, Judd, Anderson, Thaanum and I lay about in the warm sand, bare-footed, talking until after nine. Anderson, who is a wireless operator, talked with the ship three miles distant by flashing an electric torch. The moon, though not full, was so brilliant that I made notes in my pocket notebook by its light. Sooty Terns squatted in their large colony nearby and the water washed gently on the sand below us. Except that there was no shrubbery, the setting reminded me of our camp on Ocean Island.

June 25, Monday

Awoke at dawn to find clouds at the horizon tinged a beautiful rose color. Shortly after, the sun was up. Large rays, known here as diamond fish, seem fairly common here. Grant and I went in pursuit of one in the skiff and I had a chance at it with the harpoon but missed. Immediately adjacent to the tents is a large colony of Sooty Terns, most of them with young now, from recently hatched to a week old. Adults are clamorous all through the night and redouble their noise by day. As the sun is intensely hot, I cautioned men against going through among the terns to avoid mortality among the young. When the light was sufficiently strong for photography I went out, collected some terns, adults and young, and took a series of pictures.

At one end of the island we discovered a cache in which a hammer, saw, nails, ship's compass and other similar articles were wrapped in a sail and thrust under a log. Nearby were stakes and other refuse from a camp, evidently of Japanese. Apparently the crew of some wrecked sampan had lived here for a time and had then been taken off, perhaps 18 months ago. The time that had elapsed since the camp had been abandoned was indicated by the condition of the canvas, etc.

In the afternoon we visited a little sand spit a mile and a half toward the northwest, the most distant land in this direction. The island, which we called Shark Island, was of curving form, narrow, 200 yards long by 15 yards wide at the widest point. It supported no vegetation and the only birds on it were a few noddies and Hawaiian Terns resting here for an hour or so and a frigatebird or two. I shot four Hawaiian Terns on the wing that fell in the water. Sharks immediately began to circle about them rising to the surface and cutting curving circles about the birds preparatory to eating them. When one came too close I shot it in the back with a load of #6 chilled [shot] and it would rush away to be

replaced immediately by another. In all I fired seven or eight shots in protecting my specimens before Anderson came with the boat to retrieve them.

Palmer is making a new map of the shoals in which he is locating the various spits. The names bestowed upon them have been more or less fanciful and the islands themselves are not permanent but seem to shift in form and outline. The one visited today was near the outer reef and had much coarse coral and shell thrown up on the beach in lumps as large as my fist. Here while loading into the launch we caught a sand shark six feet long entirely dark above. I saved the head and had the jaws cut out to show the teeth. A wonderful night tonight with moon almost full and the air soft and warm. It is a pleasure simply to lie out on the fine white sand, to sift it through my hands and to work my bare feet in it. It is wholly clean so that it shakes off leaving no dirt whatever.

Anderson tells me that on Washington Island ducks come to the freshwater lake in large numbers from November to March. Several species are represented, among which is the Spoonbill [Shoveler, *Anas clypeata*] and one known as the "Canvasback" that may be a scaup [*Aythya* spp.]. The lake is a mile and a half long and has a peat bog at one end with bulrushes growing in it. Ulua (*Carangus* [= *Caranx*]) are found in the lake, a fish known as "awa" and a large eel. On one occasion a canoe eleven feet long was dug out at a depth of eight feet in the bog. Anderson's grandmother, by the way, was a Penrhyn Islander. He speaks Manihiki [northern Cook Islands] and Gilbert languages fluently, is an expert diver, one of the best in the islands, who has gone down 8 fathoms, and is skilled in the handling of boats, nets and similar affairs.

June 26, Tuesday

Extremely hot today with one or two showers of rain. During the forenoon I made the round of Tern Island where the camp is located, to collect some specimens wanted and to secure photographs. At eleven thirty we had lunch and at twelve Commander King came in the motorboat to take the party for a cruise to some of the other islands.

The water was calm and travel pleasant. This western part of the lagoon is shallower than the eastern and has many coral heads and small reefs that almost reach the surface so that navigation is more difficult. Our first call was at an island 2 miles east of the camp, called Trig Island. This island was 225 yards long by 125 yards wide and was nearly circular in form. It rose from 8 to 10 feet above the water and had the summit covered with a fair growth of grass, *Portulaca* and *Boerhaavia*. On the western end of this island I found from 1000 to 1500 dead Sooty Terns, all young birds still unable to fly. The carcasses were old, apparently those of last year's birds. They lay in little piles in slight hollows at extreme high water mark as though they had been washed in here by a heavy storm. I believed that Tern Island had been swept on its low eastern end by a heavy gale and the young tern from the colony drowned and washed ashore here. There was considerable turtle sign on the beach.

From the point we continued east and north to two small islands near the outer reef. These two were separated by a channel 150 yards wide by [dimension omitted] are probably joined at times by the shifting sands, as the water was not deep. The first of these, named Skate Island, was 200 yards by 100 yards wide and rose 8 to 10 feet above sea level. Its surface was coarse coral sand with scant vegetation of grass, *Portulaca*, *Boerhaavia* and *Tribulus*. Humus was slight and plants low and scattered. Remains of a number of large turtles lay scattered about here and I picked up one skull and a young turtle dried to a mummy.

Figure 27. William G. Anderson with a net filled with moi [threadfish, *Polydactylis sexfilis*]. French Frigate Shoals. June 26, 1923.

I crossed to the next island called Whale Island in the skiff. It proved to be somewhat curved in form 400 yards long by 125 yards wide and rose 10 to 12 feet above the sea. It appeared to be the oldest island in the entire group and had the upper surface covered with fine gray soil. Plant life was more abundant here and consisted of *Chenopodium*, *Portulaca*, *Tribulus*, grass and *Boerhaavia*. In general, conditions suggested those found on King Island but there was less sand mixed with the soil. Some flat blocks of coral rock had been built into a fireplace about which were turtle bones. On the highest portion of the island I found remains of a shed, apparently of Japanese construction. It had fallen over and was evidently ten or twelve years old if not more. Skeleton of a small whale was cast up on the beach here and I collected the cranium and all

other bones we could find. The ear bones had disappeared. [This specimen, which gave the island its name, is a pygmy sperm whale (*Kogia breviceps*, USNM 243857)]. It was after six when we reached camp for a late supper.

Table 4. Seabird populations of individual islands of French Frigate Shoals, compiled from tabulations scattered through Wetmore's journal. Ten pairs of *Sula dactylatra* were the only birds mentioned for Gin Island. pr = pair, yg = young.

Species	Round	East	Little Gin	Trig	Skate	Whale	La Perouse	Tern
Diomedea nigripes	90 yg	75 pr	150 yg	50 yg	30 yg	90 yg		8 yg
Diomedea immutabilis		100 pr		1 yg	1 yg	25 yg		
Bulweria bulwerii							1	1 pr
Puffinus pacificus	50 pr	1750 pr	20 pr	50 pr	30 pr	500 pr	50	250 pr
Puffinus nativitatus		2 pr						
Phaethon rubricauda		4 pr			1 pr		6	
Fregata minor						60 pr	5	
Sula dactylatra	30 pr	150 pr	8 pr	20 pr	40 pr	70 pr	20	8 pr
Sula leucogaster							30	
Sula sula					1 pr	15 pr	30	
Sterna lunata					15 pr	15 pr		
Sterna fuscata				2000 pr	800 pr	125 pr		3500 pr
Anous stolidus	150 pr	400 pr	125 pr	150 pr	200 pr	300 pr	800	500 pr
Anous minutus							150	
Procelsterna cerulea							20	
Gygis alba							300	

June 27, Wednesday

A shower of rain fell at daybreak but only continued for a few minutes. I began work early on frigatebirds, young terns and other specimens collected yesterday and completed them by eleven. We had lunch again at eleven thirty and at noon left in the motorboat for the rock which the surveyors had call La Perouse Islet. The wind turned east last night and has been blowing fresh so that the lagoon was blown up in short choppy waves. La Perouse Rock is about 150 feet high by 150 yards long. A smaller rock 75 by 25 feet, 15 feet high, lies 75 yards west of it. There are rock shelves on both north and south sides of the main islet. We landed from the surfboat on the south side without difficulty. Large opihis covered the rocks and I found one pool literally filled with several hundred anemones. It gave the appearance of a flower garden as all rested with opened heads. The rock was volcanic, coriaceous in nature, black in color. In places it was encrusted with mineral matter, yellowish or whitish in color washed down from the guano above that at times formed small stalactites. Sloping shelves gave access to the lower portion but the top was inaccessible because of the loose nature of the rock. The island can be scaled on the western end but we busied ourselves with collecting and did not attempt this. The rock rises in two rounded points with a slight saddle between. It is only about 150 feet wide at the widest point. The summit is white with the excrement of birds.

A Love Bird that Schlemmer collected fell from his hand as he clambered along the cliff and dropped into the water below. Immediately a school of the black fish (10 to 15 inches long) known as [space left blank---possibly the triggerfish *Melichthys*] attacked it and tore it in pieces and devoured it. We reached camp again after six. I had supper and

then worked on skins until dark. Sent Schlemmer with Grant to aid in collecting fish. Another beautiful moonlit night tonight with soft balmy air blowing in from the sea.

June 28, Thursday

Awake this morning at five to work for a time on notes. The island [Tern Island] is about 600 yards long by 150 yards wide. The eastern half is a long curving sand spit from 6 to 8 feet above the sea which is swept in time of storm. The western half, which is the site of the bird colonies is from 10 to 12 feet above the sea and has a sort of fine coral sand on which grows grass, *Boerhaavia*, *Portulaca* and *Tribulus*. The Sooty Terns occupy the entire eastern portion of this section and the shearwaters are found in an area of loose soil near the center. The noddies nest at the west and on the borders of the Sooty Tern colony. Today Bryan set out potatoes and onions left from our camp supply. Following is a list of seeds etc., planted by Judd on this island June 26:

Cocos nucifera	coconuts	5 sprouted nuts
Hibiscus tileaceus	hau	30 slips
Calophyllum inophyllum?	Hawaiian Kamani	seeds
Thespesia populnea	milo	"
Casuarina equisetifolia	ironwood	"
Pritchardia pacifica	Fiji fan palm	"

At eleven we were packed, broke camp and went aboard ship where everything was stowed and we were under way at 1:00 in a sudden heavy shower of rain. As we passed out toward the east across the lower end of the shoal we sighted another island which we named Disappearing Island, as it alternately appeared and disappeared amid squalls of rain. It was apparently a bare sand spit 300 yards long with no indication of vegetation. There was a strong swell outside but we ran slowly and so did not notice it much.

NECKER ISLAND (Second visit)

June 29, Friday

At daybreak this morning we anchored at Necker and at six Judd, Cartwright, Anderson, Caum, Palmer, Bryan, Schlemmer, and I landed at Buccaneers Landing with no difficulty, for a day ashore while Commander King ran a line of soundings to locate some shoals near the island. Cartwright remained to map some of the heiaus on the island while the rest of us proceeded to examine some caves. The first cave, one located by Caum during his work here, faced the west and was under an overhanging ledge on a steep rock face. For a space 18 x 6 feet the cave was paved with flat stones against a wall built across the front. The sea lay 60 feet below. We found nothing of importance here. We continued then to the cave located by Anderson, which lay on the eastern slopes seventy feet above a broad ledge barely exposed above the sea. This cave was 40 feet long by 10 wide. The approach was along a series of narrow ledges with poor footing along which Anderson carried a screen 4 x 10 feet to use in sifting. We excavated and sifted all the earth in the floor of this cave at one end, digging down three feet, while at the other the rock shelved up until it was exposed. The cave had been paved and was evidently used as a habitation. A wall had been built up along the front, and earth and rock had been filled in behind. Among the first finds were a human femur and two tibiae in good state of preservation. An end of one of the bones was charred by fire, perhaps significant of a meal of "long pig." A fireplace had been made against a large upright stone, below which were bits of charcoal and considerable ash cemented into a firm mass. At depths of from one to two feet we

found parts of three or four broken stone bowls and by sifting discovered three of the curious ground stones said to have been used in catching squid, two of them 3 to 4 inches long and two inches wide and one only a little more than half as large. Also some little adzes sharp at either end, smooth and polished and some large flattened stones with polished surface.

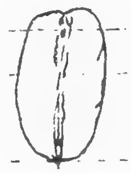

Figure 28. Wetmore's sketch of a grooved stone from Necker Island. These rather common objects used as sinkers for Hawaiian octopus lures.

Figure 29. Wetmore's sketch of a stone adze from Necker Island.

Scattered through here were many water-worn pebbles two to four inches in diameter. One of these I kept as a souvenir. Also found quantities of sharp-edged rock slivers probably used in making bone fishhooks. All in all we made a good haul and felt well repaid for a hard morning's work. We returned at one to our camp site where we had lunch. I made some interesting observations on birds, took some photos and spent part of the afternoon in writing up my notes. We embarked about five and stood off at once toward Kaula against the usual strong ENE breeze. [Historical notes inserted here duplicate information in Clapp and Kridler (1977) and are omitted.]

Kaula Island

June 30, Saturday

We passed south of Nihoa today and hoped to reach Kaula before dark but head winds retarded us so that it was past eight before the island was sighted. There was no good anchorage here so that we simply lay to for the night.

July 1, Sunday

At daybreak this morning we were nearly out of sight of Kaula but soon ran back to the island and made a circuit of it. At seven the surfboat was put over in the lee of the island and we were towed around to the windward side. As Kaula on the chart is marked as 940 feet high I was astonished to find it a rounded mass rising somewhat less than 500 feet above the sea, a veritable turtle shell of volcanic rock with its rounded summit and high sides. The island was steeply precipitous for three-fourths of its circumference, the cliffs rising almost sheer for 200 to 300 feet with nothing more than shelves, barely above water level, at the base. On the east-southeast there was a slight indentation that formed a bay with precipitous walls, not quite so high as elsewhere. From close examination I was convinced that the summit could be scaled at the southern extremity of this bay, where the cliffs were not more than 100 feet high, and their front was broken by a series of ledges. It would be difficult to descend here but the feat could be accomplished by taking up a long rope and fastening it above and then using it as a support in descent. Once over the cliff there is a long slope to the summit. The upper surface of the island is rounded and has

considerable soil. It supports much vegetation, partly herbaceous and partly shrubby. There is a clump of dark green bushes on the northern summit. The island is one third of a mile long by half as broad.

On the northern face is a huge cave sixty feet in diameter by nearly 200 feet deep, the famous cave of Kui Moana, largest shark god of the islands, whose form turned to stone may be made out at the entrance. White Terns nested above its dark entrance a spot of white against a somber background. We turned the surfboat and worked back for over half the length of the cavern to note that it ended in a narrow trench cut in the rock. Our voices echoed from the damp walls and the water showed dim and uncertain depths below, in whose changing lights boulders loomed like mysterious animals of the deeps. The contrast with the light and air without was remarkable.

We went nearly around the island in the surfboat but were forced to give up thought of landing because of the surf. At the southeast point there is a submerged ledge over which surf breaks heavily. With the wind blowing directly on it landing is impracticable. Landing may be made in moderately calm weather with wind south or west. Birds were very abundant. In the lee of the island I shot a Necker Island Tern and a Gray-backed Tern. It is not improbable that investigators will find a peculiar passerine on the island. [The first landings and biological investigations of Kaula are discussed by Bryan (1942). No native land birds, passerine or otherwise, were encountered there.] At 8:30 we boarded the TANAGER and stood away at once for Honolulu were we arrived at 11:15 p.m. Registered Blaisdell Hotel.

HONOLULU

July 2, Monday

At eight this morning I went down to the TANAGER after leaving photos to be developed etc., and got stuff off for shipment etc. Also made up food lists etc. for the Johnston Island trip. Busy with mail for rest of forenoon. Lunched with Gregory and discussed plans. At 2:00 p.m. I had an appointment with Commander King at his office, met Capt. Tarrant and other officers of the mining squadron and discussed plans for the Johnston Island trip. It was arranged to send the entire squadron with the exception of the TANAGER, which will be laid up to clean boilers to Johnston Island. The fleet will consist of the minesweeper WHIPPOORWILL and two destroyers the LUDLOW and BURNS. The scientific party will have accommodations on the WHIPPOORWILL. We sail July 7. Returned then to the TANAGER and oversaw transfer of material needed, supplies, camp equipment etc. from the TANAGER to the WHIPPOORWILL which completed the afternoon.

[July 3-6 in Honolulu]

July 7, Saturday

I admired the longitudinal shadows on the huge pali and the hills beyond this morning and then enjoyed a pleasant breakfast with Commander and Mrs. King. At 7:30 a car called for us and we returned to Honolulu. At 8:15 I was at the Blaisdell, completed my packing and had my baggage sent down to the WHIPPOORWILL. Arrived at pier 5 myself at 9:15 and spent a busy half hour in greeting people and in checking up on the outfit in general. At 9:45 we sailed to Johnston Island on the U. S. minesweeper WHIPPOORWILL which also carries a small hydroplane with Commander Rogers and a pilot who will make aerial photographs of Johnston Island. The WHIPPOORWILL is convoyed

by the destroyers BURNS and LUDLOW with Captain Tarrant in command. All told we made an imposing array as we steamed out of the harbor. The WHIPPOORWILL had barely reached the buoys of the channel when a sea plane stood in with a parcel for Commander Rogers so that we stopped in mid channel and put over a skiff to receive it.

We were soon heading southwest from Oahu on a straight line for Johnston Island with a following wind that merely gave us a lurch and a roll, not at all uncomfortable. The WHIPPOORWILL, with a small sail raised to increase her speed, held the position to the left, with a distance separating her from the flagship. The other destroyer was a thousand yards away again, beyond the flagship. The three ships steamed abreast in this fashion all the afternoon. The WHIPPOORWILL is a sister ship of the TANAGER and as on our own ship our cots were ranged on the quarter deck where we slept, loafed or read during the afternoon.

July 8, Sunday

A quiet day with a following sea. A few flyingfish about, a few Wedge-tailed Shearwaters and an occasional Bulwer's Petrel, nothing more.

July 9, Monday

Wedge-tailed Shearwaters more abundant. No albatross at all.

JOHNSTON ISLAND

July 10, Tuesday

We sighted Johnston Island at 10:40 a.m. after a long watch. Sooty Terns and an occasional frigatebird came flying up from the south or an occasional booby swung in to look us over during early morning, indications that land was near. When finally sighted, the island loomed up as an indistinct yellowish haze with its outlines faintly indicated, near ten miles distant. We sighted the northern side. The ships ran along parallel to the island until it was nearly out of sight astern and then swung in on the southwestern side to an anchorage two miles south and a little east. There was not a perfect lee here but there was no swell, merely a chop from the east-southeast breeze. There was some delay after coming to anchor but we were finally under way about three in the motorboat, towing the surfboat and a skiff behind. In the confusion of starting, one of the skiffs was overlooked and the surfboat had to return for it while we stood by in rather a nasty chop. We were finally off and ran in to half a mile of the beach. There was a mass of coral heads beyond but with a light load we were able to go in to the sand without especial trouble.

The soil inland, where it was grown with grass, was badly cut by shearwater holes so that I located camp on the highest part of the only available stretch of beach, which was on the southern side, just east of the extreme western point. By placing the tents back against the grass we were able to put them four feet above ordinary high tide. In our first load I put personal luggage, tents and water. Through some oversight, tent pegs were omitted, though I had asked for them, the first of a series of mishaps that marked the making of this camp. We laid the tents out in place and then waited for the second load. I had left Grant and George Higgs, the cook, to attend to embarking it. The tent pegs arrived with food and other material and five tents and the tent fly were soon in place. We discovered then that kerosene had been overlooked! and we were dependant on coal-oil

stores for cooked food. [A historical note inserted here is omitted, as is the personnel list--see itinerary.]

To add to the pleasures of the day the launch was delayed by engine trouble until she was caught by the falling tide. Anderson, Schlemmer, Bryan and I went off in the skiff to help them out but were unable to budge them. We returned after dark to shore, bringing Commander Rogers with us to spend the night. We had a cold lunch. I sent some food out to the stranded launch and then turned in. The boat finally came off with the rising tide at 3:00 a.m.

July 11, Wednesday

I walked up the beach at five to pick up some bits of wood for a fire and was returning with a bundle of barrel staves when I met Anderson with the news that we had no cooking utensils, another mishap to add to those gone before. The men made coffee in their cups over a little fire on the beach. The launch came in at 6:30 and I went out in the skiff to find that they had brought me coal-oil and the cooking utensils. I spent an hour or two in arranging camp and then with Schlemmer walked around the beach, collecting a tropicbird, a tattler and some young petrels. On our return we picked up some frigatebirds. I spent as much of the day as possible on my notes but had many interruptions, as several boats came ashore. I warned the men to be careful with cigarettes to avoid firing the dry grass on the island. Camp is now fully established. We have five tents and a tent fly ranged in a row at the highest point of the beach, three tents for sleeping quarters, a fourth for general stores, and a fifth for the kitchen.

July 12, Thursday

The sand in early morning is dotted with myriad pointed dots and impressed lines, tracks of the multitudinous crabs that emerge from holes, blown smoothly over during the day time, and wander over the entire beach covering it systematically in their search for refuse.

Last night Schlemmer and I walked down to the east point of the island and collected a series of Blue-faced and Red-footed Boobies. Frigatebirds roosted in open rows on little stones and on rock ledges where gathered little companies of Red-footed Boobies nesting sociably against one another, asleep or busy preening their feathers in the darkness. It was great fun to poke a flashlight at them and see them gaze stupidly at it, or alarmed at some noise flop awkwardly away. Blue-faced Boobies rest in a close band on one long, rocky point, standing with flat feet on the stones rather than perching on sharp projections like their smaller brethren.

The light revealed thousands of scavenger beach crabs that watched intently or scurried away as we approached. These varied from white to deep ruddy in color. Larger water crabs scuttled out over the rocks into the water. It was interesting to throw the light into the cavities and cracks of the higher rock ledges, where large cockroaches were brought out in sharp relief or Bulwer's Petrels old and young were brought into view.

Today was clear as usual with a steady tradewind from the east, refreshing as it tempered the heat. Though this steady breeze may seem disagreeable to those not accustomed to wind, to me it is pleasant in its unvarying regularity. I enjoy its feeling on my face, neither hot nor cold, serving to temper the intense heat of the sun. We prepared specimens until afternoon. At two I walked out and took a series of photographs.

Yesterday a party of men landed and at either end of the island spread white cloth on the ground to make a great cross 75 feet long and six feet wide. One of these was placed at either end of the island. Early in the morning the ships moved around to the western side of the reef where there is anchorage close in to the reef and a lee affords calm weather. The hydroplane was put over here and the aviator made a flight to secure photographs at 10,000 feet. The white crosses serve to give the scale. The plane crossed the island first at an elevation of about 600 feet. As the drumming of the motor came overhead, the terns rose and circled over their colony while the frigatebirds circled off to sea not liking the appearance of the stranger.

Figure 30. The hydroplane flies over our camp on Johnston Island.
July 12, 1923.

After a forenoon occupied in skinning birds, I went out after lunch and took photographs and explored the island in general. Johnston Island is approximately a mile long by one-fourth of a mile wide with its long axis running slightly south of west and north of east. It is roughly rectangular with one or two small indentations cut in its shore

line. The greater part of the island lies from 10 to 15 feet above sea level with a conical elevation at the eastern end 40 feet high, below which the slope drops steeply to the eastern beach. The beach is made of fine coral sand and the soil of the island is of the same material with comparatively little humus. A heavy growth of tussock grass covers the entire island with considerable amount of *Tribulus cistoides* scattered through it and occasional plants of *Boerhaavia* bordering the beaches.

The island is built on a low platform of a fine-grained rock, apparently a sandstone elevated at its high point about seven feet above sea level. This rock, gray in color, is exposed in worn ledges on the east and north, and elsewhere appears as level shelves from which project low pyramidal points or curiously eroded columns. It is fine and hard in texture. The ship can anchor safely 750 yards from the outer coral heads to the south of the island, inshore from this are broken coral heads and finally a flat reef that is exposed at low tide. Small launches may run in to about 1/3 of a mile from the beach on the south. Boats of two feet draft may pass to the beach at high tide. Inside the inner reef is a shallow area sprinkled with small coral heads. Camp is located inside the southwest point on one of the few clear beaches.

There are a few logs of fir cast up on the beach, one with roots attached. A crude hut with a cast iron roof has been erected on the shore south of the eastern hill. Lumber and some barrels lie scattered about, said to have been brought here by Ai[?] a Chinaman from Honolulu who intended to establish a fishing station here. His crew revolted, however, after landing the supplies, and the project was abandoned. In a slight hollow below the western side of the hill I found remains of a much older hut erected by a white man who lived here at one time. On the summit of the hill is a head board that may mark a grave.

About four I came out on the eastern beach where Anderson was fishing. We called down a flock of immature frigatebirds who snatched at small mullet held in Anderson's hand above his head or that swooped at, and occasionally caught, small fish thrown in the air. Anderson talked with the ship at dark by means of a flashlight. About eight we went out and took some flashlight photos of roosting boobies and collected more for specimens. Destroyers left for Honolulu.

July 13, Friday

The flattened sand louse recorded at Nihoa and French Frigate Shoals is very abundant here and is a decided nuisance, as at night it invades our cots, crawls all over us and sucks our blood. The bites swell, turn red and itch severely, the burning sensation and swelling continuing for several days. The creatures crawl out of the sand and do not make an appearance until I have been asleep for an hour or so. I awake then and with the light of an electric torch kill 30 or 40, when I can usually sleep in peace for the rest of the night. [Following accounts indicate that this was a tick. Two species of ticks of the genus *Ornithodoros* occur commonly on Johnston, where their populations have been monitored in some detail (Amerson and Shelton, 1976).]

Was occupied until noon with the care of specimens and notes. It was extremely hot today with a glare of the sun that was trying to the eyes. Showers passed in the afternoon, cooling the atmosphere, and a heavy rain fell for fifteen minutes at night. Afternoon Schlemmer came in and reported Necker Island Terns. I went out at once and was fortunate enough to secure two of three seen. Also located a small colony of Gray-backed Terns. Bryan, who was at Sand Island today, reported what he thought was a

White-tailed Tropicbird but I consider the identification doubtful. In a hollow southwest of the hill I found remains of several thousand Sooty Terns, Wedge-tailed and Christmas Island Shearwaters that had been killed by plume hunters and the bodies thrown in a pile after the hand carrying the primaries had been cut away. Careful examination showed that the skeletons were complete except for the hand. In all the mass of bones examined I found no metacarpals. None of the rest of the plumage had been taken as the bones were held together by a felted mass of decomposed feathers. I judged that the work had been done during a few days at most and that it had taken place when the lumber and other supplies on the beach had been landed. Apparently an attempt had been made to burn the bodies, as the surface of the deposit was charred. I was out again from eight until nine thirty on a circuit of the island to collect some boobies still lacking in the series of skins preserved. Much careful search for petrels but found none, though I located another colony of Christmas Island Shearwaters.

July 14, Saturday

Preservation of specimens occupied most of the day. It was cooler today though the wind increased. Early in the morning I walked out and collected two juvenile Christmas Island Shearwaters. I found them extremely fat. In the evening at low tide Schlemmer, Anderson and I sailed out in one of the skiffs to the outside reef where we tied up to a projecting block of coral to wait for low tide. Dozens of shearwaters came scaling in from the open sea toward the island in company with a few belated terns. The screaming calls of the sea birds on the island, nearly a mile south, were heard only indistinctly at intervals above the wash of the surf on the reef. While waiting I waded about with a water glass examining the bottom. Corals of half a dozen species were growing in abundance over a broad platform in shallow water. Jagged holes five or six feet deep were natural aquaria in which swam brightly colored reef fishes. Huge holothurians twelve inches long lay sprawled everywhere. Nooks and crannies were occupied by sea urchins, two species with sharp spines to be handled with caution. When feeding the spines were thrown together in clumps that spread to bristle as a protective armour whenever the animal was touched. Two other species had long blunt spines that were strong and heavy. The larger of these lived in the wash on the outer reef.

At dark the reef was bare in the tide and we walked along shining our flashlights in little pools. Strange fishes darted out, among them many eels. Anderson today killed a huge eel 5 feet 4 inches long and 8 inches in diameter. He struck at a fish with his spear but missed, when the eel struck quick as a flash at his harpoon point. The great creature was enticed out of its crevice in the coral bank by some bits of fish. After several attempts he succeeded in thrusting a spear into its thick hide but it was nearly half an hour before he was able to lift the writhing beast into the boat. Its sharp pointed teeth and heavily muscled jaws made it necessary to handle it with caution. We found several beautiful *Cypraea tigris* in holes in the outer reef and a few *Tonna*. Spiny lobsters were common. When speared they made a squeaking noise. About ten we started back but were two hours in the return and finally had to tie the boat a hundred yards from the shore of the island as the tide was so low that we could not get in. We skirted coral head after coral head and to add to our difficulties broke an oar on the start.

July 15, Sunday

At seven this morning Schlemmer and I rowed over to Sand Island with Dr. Pollock as company. We landed after a stiff hour's row against wind. Sand Island lies a

mile north of east of the main island. It is about 330 yards wide by 400 yards long with a small peninsula projecting toward the northeast. It rises fifteen feet above high water at the highest point. The island rests on a shelf of sand rock that is laid bare at several points on the beach. On the east the exposure is about 4 feet high. On the north at one point it is 8 feet above the water. As on the main island there is a soft layer of rock covering a harder one. The soil of the island is sand with a small mixture of humus. It supports an abundant growth of grass, *Tribulus* and *Boerhaavia*. I found the skink and collected one[4]. The bird tick was abundant.

Figure 31. W. G. Anderson with an eel. Johnston Island. July 14, 1923.

A few Common Boobies and Red-footed Boobies rested on rocks off shore. Two turnstones and two Golden Plover were noted. The Sooty and Gray-backed Terns had

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[4]The Snake-eyed Skink (*Cryptoblepharus poecilopleurus*). In stating that this introduced species was found only on Johnston Island proper, Amerson and Shelton (1976) overlooked the present specimen, which is recorded in the USNM catalog as being from Sand Island, although it is credited to Bryan rather than Wetmore. A specimen of this species from Sand Island is also on the list of reptiles sent by Stejneger to Gregory. Apparently this lizard has not been encountered on Johnston since the visit of the TANAGER (Amerson and Shelton, 1976).

young on the wing. Blue-faced Boobies and Christmas Island Shearwaters were well grown, about half the noddies were hatched. Frigatebirds and tropicbirds were not now nesting. There was no evidence that the birds had been molested.

On the western half of the island were deposits of guano, part soft and a part consolidated. Someone had excavated some of the solid rock and made a pile of it. I found one bird bone, some crab claws, and many shells in fragments of the rock. This guano is simply the consolidated sand and earth of these islands where it is mixed with the excrement of birds. On these islands the deposits are due mainly to albatross, frigatebirds and boobies. Terns and shearwaters are too small to produce excrement in sufficient quantities. Nest sites of the three species mentioned are covered with solid masses of their dung sometimes of considerable amount.

Between Johnston Island and Sand Island are lines of reef running northwest and southeast from 25 to 50 yards apart with from one to six fathoms of water between. The aviator informs me that three miles east of Johnston is an extensive rock flat, bare at low tide. It is my belief that Johnston Island formerly was much more extensive and that it probably covered all this area but has been eroded away. My belief in its antiquity is based on the formation of the base rock and the manner in which it is plainly being cut away and on the presence of guano.

There were several redwood logs on the shore of Sand Island and a board erected on the highest point similar to one found on the hill at the main island. We collected a number of birds and I took a series of photos. After lunch skinned birds until the tide came in, about two thirty, and then sailed back to camp. In the evening went out with the flashlight and collected a series of terns.

July 16, Monday

Today prepared specimens secured last night. In the afternoon went out and took a series of photos of noddies and others. At eight p.m. went out and secured a series of Bulwer's Petrel. A tick that lives in the sand is very bad in this camp. The creatures crawl out at night and bite severely, the spot itching and swelling severely and giving trouble for several days. Tonight after an hour's sleep I awoke and killed 92 of the animals on my blankets.

July 17, Tuesday

This day was occupied in completion of collection and in examination of certain areas to make sure that I have overlooked no petrels. The wind freshened somewhat today and there was rain at night. It is distinctly warmer here than farther north but still not oppressive. Morning and evening temperatures run from 75° to 80° F. and I sleep with a light blanket with no discomfort. Tide rises and falls here 32 inches according to a stake set in front of my tent.

Our work here has been rounded up in good shape with everyone working hard but without the crowding to get through that we have had in some places, a grateful sensation. About ten thirty this morning I walked out to collect some Gray-backed Terns and remained out until noon. Was occupied with notes and specimens in the afternoon. In the evening Dr. Pollock, Dr. Edmondson and I indulged in a long talk on various aspects of evolution. About eight thirty I walked up to the east end of the island and caught a Red-footed Booby for the alcohol tank. The air was warm and somewhat humid, tempered by a stiff breeze

from the east that blended the cries of terns and the moans of shearwaters into a subdued roar that was barely audible above the wave wash on the beach. A quarter moon shed a dim light that made use of the searchlight unnecessary except where I crossed pointed rocks. Shearwaters dodged between my feet, noddies rose in my face and dim ghostly forms of frigatebirds hung in the air overhead, silent companions of vulturine sinister aspect from whose inspecting one is never free. As I walked along I meditated on strange happenings that may have taken place on this remote bit of land. On the strange birds that may have colonized it during the distant past when it covered a much larger surface, of their life and loves and deaths, of possible visits by savage men, Polynesians driven from their course in journeys from Hawaii to the south or in return from southern wanderings, men perchance who landed here to rest, fish and recuperate for days or weeks and then continued northward guided by constellations in the sky, or others of white skins drifted here from lost ships who, less skilled in wresting a livelihood from an arid land, perchance died of thirst in some obscure hollow where they were covered by drifting sands, of poachers who with murderous hands destroyed thousands of the bird inhabitants for the sake of their wings. The air seemed filled with ghostly whispers of these ancient happenings and with a creeping along my spine I was almost prepared to visualize some of the scenes conjured so vividly by my imagination.

July 18, Wednesday

Rain during the night but clear this morning with a good breeze. Planted 8 slips of Hau *Hibiscus tiliaceus* this morning on a slope near camp. Spent almost the entire day in working on notes and correspondence and in afternoon packed collection made here for shipment.

Rain squalls came on during the afternoon and continued through the night. The wind blows slightly from the east. Ticks continue to be very bad but I have killed so many that I have only 20 or 25 at a time now. Their bites itch severely and remain troublesome for several days, with swelling and exudation of lymph. At dark received word that the TANAGER is due tomorrow.

July 19, Thursday

Completed packing this morning. The TANAGER arrived about seven thirty and followed the WHIPPOORWILL around to the western side of the reef where she received additional oil, a process that took until five p.m. Commander King came ashore about one, skirting the reef in the motor-sailer until he could get inside. With him were:

H. Palmer, geologist
D. Thaanum
J. B. Mann, topographer
Orme Cheatham, a young man to serve as assistant to Pollock and to make himself generally useful.

The airplane went up once more and made two flights over the island. I walked out with Anderson about ten and we spent an hour at the eastern end of the island watching the ships, admiring the view and making observations on the soaring birds that hovered over the slope of the hill. There was a pile of rock here that perhaps marked the site of a flagpole indicated on the chart. Mann made a topographic map of the island with Bryan's assistance.

Cheatham caught three small sand sharks in the evening, the first we have seen in the lagoon. The sketch gives relations of dorsal and pectoral fin.

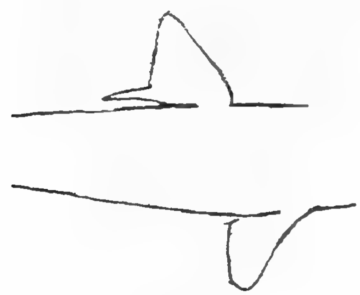

Figure 32. Sketch from Wetmore's journal showing relative positions of pectoral and pelvic fins of a small shark caught on Johnston Island.

Anderson tells me that Sooty Tern, petrels and shearwaters do not occur on Washington or Fanning Islands. The two species of shearwaters [*Puffinus*] *cuneatus* and *nativitatis* are found on Christmas Island.

Following are the birds that he knows to occur on the two islands [the parakeet would be Kuhl's Lorikeet (*Vini kuhlii*), thought to have been introduced to these islands from the Austral Islands, where it is presumed to be endemic].

FANNING	WASHINGTON
Red-tailed Tropicbird few	
White-tailed Tropicbird	White-tailed Tropicbird
3 sp. of *Sula*	3 sp. of *Sula*
Frigatebird	Frigatebird
Noddy	Noddy
Megalopterus	*Megalopterus*
Procelsterna	*Procelsterna*
Tatare	*Tatare*
Gygis	*Gygis*
Parrakeet	Parrakeet

July 20, Friday

The motor-sailer came early this morning to take Thaanum, Palmer and Mann to Sand Island. The two latter made a map of this island and Thaanum found landshells. We broke camp at nine but did not get off until eleven, as the boat was slow in returning. One load went off in the surfboat and we were able to get the rest of the stuff in the motorboat and surfboat. We left in a blinding rain squall and after fifteen minutes worked out through the reefs touching in several places but without damage. Our load was transhipped to the TANAGER without mishap and I was soon enjoying a shower bath. The sun came out and shone brightly so that I was able to take some pictures of the island. We were under way at 1:30 headed for Wake Island. A few Sooty Tern and Wedge-tailed Shearwaters about in the afternoon. At seven in the evening a Necker Island Tern came aboard and I captured it.

Table 5. Seabird populations on certain Northwestern Hawaiian islands and Johnston Island from tabulations scattered through Wetmore's journal. Wetmore did not make such compilations for all of the islands but this information can presumably be extracted from the species accounts. Numbers for French Frigate Shoals are given in Table 4. *Oceanodroma tristrami* was found only at Pearl and Hermes (see species accounts). The number of *Fregata* on Laysan is an estimate based on an actual count of 1377, and that for *Sterna lunata* is likewise an estimate based on a count. The numbers from Kaula Island are a "slight attempt at an estimate of the birds as seen from the ship." * = actual count, ✔ = present, br = breeding, pr = pair, yg = young.

	Pearl and Hermes			Laysan	Nihoa	Kaula	Johnston	
Species	Southeast	Grass	Seal				Johnston	Sand
Diomedea nigripes	✔	800 pr	1200 pr	4700 yg	60 pr			
Diomedea immutabilis	✔	100 pr	150 pr	3400 yg	2		1 yg	
Pterodroma hypoleuca	✔	1	2 yg/1 ad					
Bulweria bulwerii				750		100 +	400	
Puffinus pacificus	✔	50 pr	300 pr	77,500	15,000 pr	2000+	25,000	500
Puffinus nativitatus	✔			2000	20 pr		300	100
Phaethon rubricauda	✔	2 pr	15 pr	80*		100	8	4
Fregata minor	✔	not br	80 pr	1500	600 pr	5000	800	100
Sula dactylatra	✔			160*	125 pr	500	200	20
Sula leucogaster	✔			2*	50 pr	200	75	
Sula sula	✔			80*	3000 pr	2500	250	
Sterna lunata	✔		150 pr	1800	5000 pr	4000	25	25
Sterna fuscata	✔		3	12,000	6000 pr	10,000	3500	2000
Anous stolidus	✔	20 pr	30 pr	500	2000 pr	5000	1500	800
Anous minutus	✔	20 pr	20 pr	600	[omitted]	1000		
Procelsterna cerulea					800 pr	25	3	
Gygis alba	1			80*	4000 pr	100	40	

AT SEA

July 21, Saturday

In lat. 17° 10' N Long 174° at 2:00 p.m. a White-tailed Tropicbird circled the ship several times. A *Phaethon rubricauda* seen a few minutes later. A few Bulwer's Petrels and Wedge-tailed Shearwaters about. A following wind of about 20 miles per hour made a comfortable sea.

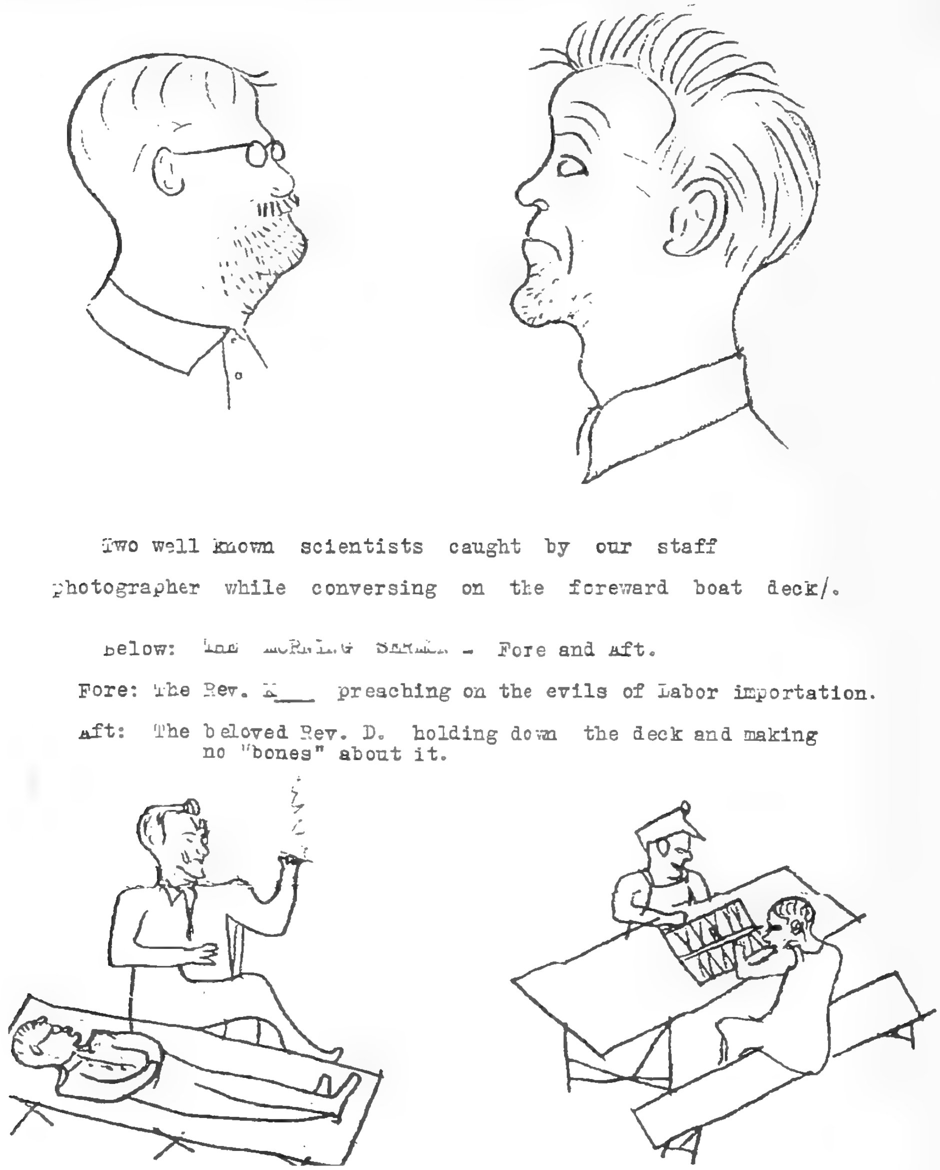

Figure 33. Page from the ship's "newspaper" captioned "Tanager Harpoon Pictorial Supplement," with caricatures of some of the members of the expedition. That on the upper left is certainly James B. Pollock and that on the upper right may be Harold Palmer. The figure with a cigarette bears resemblance to Wetmore. The initials after "Rev." do not correspond to those of any scientific member of the expedition.

July 22, Sunday

No change in weather. Occasional showers pass at night. No birds today.

(July 23, Monday

This day eliminated from the calender as we crossed the 180° meridian early in the morning.)

July 24, Tuesday

Flying fish noted today. Numbers of Wedge-tailed Shearwaters seen.

July 25, Wednesday

A moderate easterly wind continues.

July 26, Thursday

Sooty Terns appeared at intervals today and toward evening I saw a Red-footed Booby. The entire trip has given a following wind with fair weather except for occasional showers. The sea has been moderate as it had been following us so that it has occasioned no discomfort. Flyingfish appeared in abundance today. All hands tired of the voyage and anxious for arrival at destination. [Typed geographical data sheets for Wake and Marcus islands were inserted in the middle of 27 July but are omitted here.]

WAKE ISLAND

July 27, Friday

This morning at six low clouds covered the horizon with occasional rain squalls in sight. About seven Anderson and I were on the bridge and sighted Wake Island simultaneously, a low line eight or ten miles north of us. We had run slow since dark last night in order not to reach it before daybreak and had laid a course to south. We ran in toward it at once and in an hour could make out the shore vegetation clearly. The island appeared as a low, level line, light near the water's edge and dark from heavy brush above. Large blocks of stone appeared at intervals along the beach. The ship worked along until we sighted the passage in the south leading into the lagoon and then hove to in deep water a mile off shore while the surfboat and motor-sailer were put over side. The camp equipment was put in the motorboat which towed the surfboat and one skiff in to the island. We were in the lee here and found only a moderate swell. A small cove marked the entrance into the lagoon and here we found calm water. The motorboat anchored here and King, Thaanum, Anderson, Bryan and I went ashore.

I found a rough rocky beach with no sand and spent an hour in looking over the small western island and the western end of the central island for the most suitable camp site. A place was chosen 150 yards west of the lagoon entrance on the small island [Wilkes] where a little flat outside the bushes offered a surface of coarse coral and sand mixed with boulders. Camp equipment was landed here and tent set up. It was difficult to dig holes to set the upright poles because of large lumps of coral but this was finally accomplished. The tents were pegged in part and in part tied to large blocks of coral.

We had lunch at two p.m. and collecting began immediately after. I set up six tents in a row---five for sleeping quarters and one as a store tent. In addition, I put up another tent with the fly in front of it to serve as a work room and storage for my material. A heavy shower came before we had the first tent up but did no damage. In the afternoon King and I with Dr. Millard, Anderson and Schlemmer rowed across the lagoon to the third island where there was an old Japanese camp and investigated it. I collected a rat or two here. Thaanum and Grant reported a land rail seen on the large island this evening.

Figure 34. Left to right, Palmer, Bryan, Schlemmer, Anderson, Pollock. Wake Island. August 3, 1923.

July 28, Saturday

Commander King informed me this morning that the TANAGER could find no anchorage as, except at the actual edge of the reef, the water was 100 fathoms or more deep. It will be necessary for her to lie off the island during the period of our work. He thought that with care they might be able to allow us ten days here, a course to be determined by actual trial.

I went out as early as possible to secure some rail [*"Hypotaenidia wakensis"* added later in a different ink. Wetmore was unaware of this species at the time.]. Schlemmer, Carroll and I waded the channel to the large island and entered the brush on the opposite bank. We walked slowly and cautiously through small openings that led between dense thickets. There was much dead stuff banked up on all sides, some of the gnarled logs

being 12 or 14 inches through. At short intervals I paused to squeak, watching closely on all sides. After fifteen minutes when well in toward the center of the island my eye caught a slight movement at one side and an instant later I saw the trim form of a land rail somewhat larger than a Virginia Rail [*Rallus limicola*]. Three were taken here about one small opening in the space of two or three minutes and in all I took eight during the morning. The birds were alert and inquisitive and came walking out with head and neck erect and jerking tails. Though not averse to crossing open spaces, they walked ordinarily under cover, apparently through a desire to keep out of the intense rays of the sun. Often while sitting down one came within three or four feet of me peering curiously with outstretched neck and jerking tail while it uttered a low cluck. Though tame they took care to keep well out of reach, though I did knock one over with a slight switch. The birds are now in breeding condition and Bryan noted a pair in copulation today. A light brown band faintly indicated across the breast is reminiscent of *Hypotaenidia* (found in female only). The keel of the sternum is very low and the breast muscles slight.

Aside from the Sooty Tern colony on Peale Island I have found no extensive bird colonies today. Noddies and *Megalopterus* are scattered through the trees everywhere and I presume that the Red-footed Boobies and frigatebirds nest in the same way. The two latter perch to rest anywhere that a comfortable place is found. The sun was intensely hot today though showers of rain passed at intervals. The clouds banked heavily at the south in the evening and occasionally flashes of lightning below the visible horizon lightened the cloud banks.

July 29, Sunday

The sky in the east was heavily overcast this morning and about nine a slow rain began from the southeast to continue for an hour and a half. The trees offer practically no shelter so that I was very wet in a few minutes though I managed to keep camera and film dry. The temperature here ranges very evenly at from 79° to 84°, even when the sky is overcast, so that though wet I was not at all uncomfortable.

Schlemmer and I crossed the channel again and walked a mile east along the outer beach while I collected some boobies and frigatebirds. Huge blocks of a consolidated conglomerate of coral and coral sand have been thrown up at intervals, some of them from eight to fifteen feet in diameter. The beach is a band 150 yards wide of coarse lumps of corals from six to twelve inches in diameter with only a small quantity of fine material with it. The cat-eye shell *Turbo*, a large species, is abundant and I find the calcareous operculum in abundance. The margin of main shrub growth is sharply defined but scattered trees of *Tournefortia argentea* get a foothold on the rough coral of the outer beach. Inland there is more or less fine soil mixed with the coarser material. Walking is very rough indeed. In among the trees are many collections of dead branches and tree trunks swept together in windrows with large blocks of coral strewn in and over them. Apparently these have been washed in by waves and wind. Occasional old stumps of large size are found. It appears from this that the island has been swept by a typhoon from the south, perhaps 20 years ago, that tore up much of the vegetation and threw the huge blocks of coral on the beach.

Rails were much shyer today during the rain than yesterday and I had some difficulty in securing eight. They utter a low chattering call, a clattering note that is easily recognized as a rail call and also a low cluck that is audible only when near at hand. In feeding they dig up leaves and soil with a quick thrust of the head in search of shells or insects.

Today I dug two geckos from rotten wood in a large dead log. A skink is abundant and is very quick and active. They are found in or near the brush where they run over stones and branches. It is swift and hard to catch. [Geckos reported from Wake are *Lepidodactylus lugubris* and *Gehyra mutilata*; the skink is *Cryptoblepharus poecilopleurus*.] A hermit crab [*Dardanus punctulatus*] that houses in *Turbo* shells is exceedingly abundant. When the sun is hot they house at the bases of trees under stones, or in hollow logs, wherever there is shade. At nightfall or when the sky is overcast they wander in search of food. They are into everything and it is not safe to leave birds exposed at all. I have found it practically impossible to trap the abundant rat [*Rattus exulans*], as the crabs spring my traps by night or day, or if a rat does chance to find the bait first its mangled carcass with two or three crabs at work on it is all that remains in a short time. The crab climbs trees or rocks with the greatest facility so that nowhere are traps secure from them. The rats taken so far have been secured by shooting or by hand. At nightfall the wind swung back to the east and the sky cleared.

July 30, Monday.

This morning Schlemmer and I conveyed Mann and Palmer with a rodman across the lagoon to the eastern end of the large island to enable them to complete their map. We crossed then to Peale Island and remained until two p.m. Though one or two showers passed, the sky was clear in the main and the sun extremely hot when it was not tempered by the steady tradewind from the east. Peale Island has a soil of sand along the beaches that becomes a loose sandy loam in the interior. On the north, the windward side is a level flat of conglomerate that is mainly bare at low tide. At one place for a considerable area there is a surface two hundred and fifty yards wide that is almost level. In front the sea breaks heavily on our outer reef. Behind there is a rock exposure with an upward slope toward the interior of the island, with masses of coral, many of large size, thrown up into a steep-faced beach 25 feet high that forms a regular level-surfaced wall. This is near the center at either end of this island is a beach of fine sand. *Tournefortia argentea* is evenly distributed over most of the island. This tree grows openly so that it is not difficult to walk through it. Occasional small meadows were grown with grass. Toward the upper end (west) were extensive growths of *Ipomea pes-caprae* that in places had smothered low trees. The *Tournefortia* averaged 10 to 20 feet high.

Noddies nested through here and I was pleased to find a small colony of Wedge-tailed Shearwaters---near them we caught two Christmas Island Shearwaters. The rat was common through here and I shot four. These animals are active both by day and night, as I see them running about after dark when I am out with a flashlight. They are small in size and distinctly reddish-brown in color. They run about rather heedlessly as they have no apparent enemies unless a frigatebird picks one up occasionally, but see well and take refuge in holes so that it is difficult to catch them by hand. I saw one today in the upper branches of a *Tournefortia* fifteen feet from the ground. Others were seen eating the stems of *Portulaca* in little openings. They make nests, under logs or in hollow trees, of leaves, bits of grass and bird's feathers. Their tongues are stained dark by some food that they eat.

I investigated the old Japanese camp thoroughly. There is no question but that it was built by men here to collect birds for millinery uses. One building 15 by 30 was evidently used for housing. A few dishes, two pairs of wooden clog shoes, some fishing tackle and other odds and ends were strewn about. Another shed, somewhat larger, was a workshop. In this were three or four low tables made of boxes, two by five feet on top, with a tray at either end 6 x 12 inches, one for plaster paris the other perhaps for arsenic or some other preservative. A short string with a long hook tied at one end was fastened to a

Figure 35. View of old camp of Japanese feather poachers, Peale Island. Wake Island atoll. July 30, 1923.

nail at the back and probably served to hold the bird's body during skinning. An apron at the front covered the lap of the laborer. There were large numbers of trays 18 inches by four feet to dry birds and a rack of bamboo at one side to support them. Barrels and boxes of plaster paris were found and a bale of oakum. In one box were several hundred small sticks with oakum wound about them suitable for necks for birds. Scattered among the trees behind were great layers of bones, witnesses to the slaughter that had taken place. The majority were those of terns with many boobies and larger numbers of man-of-war bird. Many thousand birds had been destroyed. The houses were built of half-inch boards on a light frame with roof of galvanized iron. The living quarters had windows of glass. A small storehouse was set on poles six feet from the ground with tin guards around the poles to prevent marauding rats and crabs from climbing up. Two smaller buildings had fallen over on the ground. Two wooden cisterns of small size were noted, several large water jars, and similar things. A stay of several months had been made without doubt. It is my belief that the camp is 14 or 15 years old. In other words that the work had been done at the same time as in Laysan and probably as in Lisiansky. It is possible that one firm arranged for the taking of birds on all three islands. The huts are unquestionably of Japanese build as they show Japanese workmanship, Japanese material, and many boards are marked with Japanese ideographs. About two p.m. we hoisted sail and returned to camp. Worked until dark but had a number of birds left unskinned.

July 31, Tuesday

A heavy rain fell during the night and beat through my light tent giving me a wetting while asleep. This morning I put the fly over it to remedy matters, something that I have not had to do before. Prepared specimens until ten and then collected terns and other birds on Wilkes Island until noon. It was clear and hot all day with only one or two light showers of rain.

Figure 36. Work bench used by Japanese feather poachers in preparing birds. Peale Island. Wake Islands. July 30, 1923.

Wilkes Island has some fine sand on the inner face at the western end but for most of its circumference the shores are of coarse broken coral, worn into more or less rounded lumps with comparatively little fine material. The coarse lumps of coral extend inland through the trees clear across the island and in many places are mixed with broken limbs and trees. Many extremely large lumps lie thrown up on the beach. Apparently this island bore the full brunt of the typhoon that swept the atoll. Large trees were entirely destroyed, only an occasional stump remaining, gnarled and twisted. The tree growth here is smaller and less dense than on the main large island across the channel. The soil is rather scant and heavy blocks of coral extend clear across to the inner beach. Strangely enough no rail have been found in Wilkes Island though the birds are common on Wake Island across a narrow channel.

In a little opening at the eastern end of the island is a curious shrine that I suspect is of Japanese origin. A north and south line extends for a distance of 50 feet between two large stones, made by placing small flat stones on edge. At the center on the west is a square column of rock four feet square by five high. West of it are four smaller columns of rock about two feet high. East of it are twelve more small columns perhaps more. Some of the columns have a square wooden post at the center, four inches square by 4 or 5 feet long with three notches cut around at the top. Others have three thin boards with angular pointed ends stuck in them. The three largest boards are in the largest shrine, one of them having a series of Japanese ideographs on it. A few bottles and bits of porcelain dish and *Tridacna* shells placed at the bases of the shrines may have contained offerings.

Figure 37. Old Japanese shrine on Wilkes Island, Wake Islands. July 31, 1923.

Though evidently rebuilt by Japanese, perhaps in thanks for survival of some tremendous storm, it is possible that the site was originally built up by some natives drifted here from the south.

August 1, Wednesday

The sky clear today except for occasional drizzling clouds. No rain fell and it was extremely hot. At seven I walked east along the beach of Wake Island as far as the eastern point. For a mile the broad playa, at least 250 yards wide was composed of large lumps of rounded coral, beyond this point for another mile the washed-up material was finer but still there was very little sand. In walking it was necessary to step from one piece to another, picking each step, a rather fatiguing process. On the actual beach, at tide line, there was an extensive exposure of conglomerate sloping at a considerable angle into the sea. The elevated inner margin was broken away and the broken coral in places washed out in front of it leaving an exposed ledge, on the landward side from three to four feet high. One rock 20 feet long by ten feet had been rolled up a hundred yards from the present water line.

Occasional trees of *Tournefortia* grew out on the rounded coral and here, where not restricted by other growth assumed a beautifully symmetrical rounded form. I saw one or two plants of the slender-leaved shrub out here also. For half a mile at the eastern end the island was covered with a low rather heavy growth of *Tournefortia* bound together with many creeping *Ipomea pes-caprae*. I worked through this for some distance without finding a great deal. To the westward the fine-leaved tree alternated with *Tournefortia* in making dense thickets with small openings leading through them. Here I secured eight rails.

I cut through to the eastern end of the lagoon and returned along its border to the channel. The eastern end had broad shallows with sand bottom and a shore of fine sand interspersed with rock. A fire had swept this end of the island many years ago as was shown by blackened roots. At one point was a pool of salt water and a considerable growth of a long-leaved *Sesuvium* that covered a considerable tract. The heat was intense especially where the low trees cut off the wind and I perspired heavily all forenoon. The reflected light from the fine sand was exceedingly trying to the eyes but did not trouble me on the exposures of rough coral. A small migration of shorebirds has begun from the northward. I noted several curlew today, one tattler and a number of turnstones. All are very wild.

August 2, Thursday

At seven this morning crossed the lagoon to the western end of Wake Island. We were out a quarter of a mile from shore when Forsyt signalled to return. Dr. Millard who was with us was wanted on board ship. Morning temperatures at six a.m. have been very uniform here ranging from 76° to 81°. The heat in the middle of the day when there are no clouds seems terrific because of radiation from the coral rock composing the island, but in reality is not high, as this at one of the hottest periods that we have experienced it, was only 95°. In the sweep of the wind the heat is not disagreeable but among the low trees, where a semblance of shade is only a mockery, I perspire profusely.

The western portion of the north side of Wake Island is level, rising about 20 feet above the sea. Along the outer beach is a level stretch 100 to 250 yards wide of coral lumps stained gray from exposure. At the outer edge of this is a steep slope to the water with a level expanse of conglomerate extending to the edge of the reef 150 to 250 yards distant. Conglomerate in places is exposed as a low ledge, with strata sloping toward the sea. Inland coral rock or loose sandy soil alternate in forming the surface of the island. *Tournefortia* is the most abundant tree over this. On the lagoon side there are also exposures of level-bedded conglomerate with sand or pebble beach below. At the head of the lagoon the water is very shallow as it is filled-in by fine sand that covers the rough coral below. One or two bays here are strewn with broken bits of trees but I believe this is due to wind action, not to subsidence, as none of them seem to be rooted. At the upper end of the lagoon inland are broad stretches of sand; low-lying areas where salt water is near the surface are grown with a heavy stand of *Sesuvium*. Inland from the lagoon the box-like tree *Pemphis* is common, growing in scattered clumps that stand out as dark patches against the light sand. Near the center of this end of the island is an extensive stand of *Cordia*. A large grove of old trees has individuals whose gnarled and twisted trunks are two feet through. They writhe prostrate near the ground with short thick limbs supporting the growing branches. Beneath them is a heavy shade. Bordering this heavy growth is a dense stand of low *Cordia*, six or eight feet high, bound together with creepers through which progress is difficult. Open areas in the *Tournefortia* are often grown with *Portulaca*.

Among the open *Tournefortia* the rat was common. The animals fed on the *Portulaca* stems in the open and as we approached ran quickly to cover among the low trees where they took refuge either in hollows or in crevices among the coral. I found four in one cranny among the rocks at the foot of a tree where they had refuge with several hermit crabs. Colonies of frigatebirds and Common Boobies nested here and Red-footed Boobies were preparing to mate again. A White-tailed Tropicbird passed high overhead. These islands are absolutely clean of all refuse from the activities of the hermit crabs. I see no carcasses of dead birds at all, there are not flesh-flies and we have as yet seen no *Dermestes*. These scavengers have been eliminated by the crabs that eat everything at all

edible. During the heat of the day they are inactive and seek shade at the bases of trees, under rock ledges or stones, where a hundred or so may collect in one place. As the sun sinks they come walking slowly out, with some suggestion of turtles in their deliberate gait, with shell held on the back. At this time it is not safe to leave birds or other specimens exposed, as inevitably the crabs will be at them and destroy them. They even steal our soap and eat it. Their total number here is many thousands. I suppose that some of the *Turbo* shells that serve as homes have been used by generations of the animals as they appear old and worn.

August 3, Friday

Tide was about full this morning at seven. The channel near camp that leads into the lagoon is shallow at either end and deeper in the middle. While it is 80 or 90 yards wide, the boat channel through is narrow because of obstructing coral heads and is practicable only for small boats. Through the middle, in places it is 3 or 4 feet deep, but at either end there is only one to two feet of water. As the tide lowers, the current through here is strong. The lagoon itself is very shallow at the eastern end. A shallow shelf extends out for some distance from either shore while through the center there are depths of six to ten feet. The bottom is fine sand with many coral heads, some of them awash.

On the inner side of Wake Island a conglomerate exposure with much loose, broken coral rock lying in it forms the shore for a distance of half mile from the channel. Beyond this point the shore is of fine coral or sand with large blocks of conglomerate distributed irregularly through it. About three quarters of a mile east of the channel a low, level, sandy area is grown heavily with *Sesuvium.* The low area extends inland practically across the island and probably marks an old channel from the sea to the lagoon. Near the lagoon is a salt water pond and inland from it are two other small pools of brackish water. Beyond the low tract is constricted to a dry gully two or three feet deep that merges finally with a broad coral-boulder flat that extends across to the track. The small-leaved *Pemphis* and the umbrella tree *Tournefortia* grow on either side. The little open meadow carpeted with *Sesuvium* was an attractive place and I spent most of the forenoon here. Animal life was abundant, the green of the *Sesuvium* covering the sand was soothing to eyes irritated by the glare of the beach outside, and a steady breeze from the east tempered the heat of the sun.

About fifteen rails were seen at different times in the shrubbery or at the edge of the *Sesuvium.* They ventured out ten or twelve feet from the edge where they walked about unconcernedly, so long as I was quiet, but skipped rapidly to the protecting shelter of low growing trees at any suspicious movement. Ordinarily their motions are deliberate and they pause frequently to dig with sidewise thrusts of the bill in the loose soil to expose shells, insects or other desirable food. When I squeak they reply with a rattling chatter that is unmistakably a rail call and come running toward me under the brush. Near at hand they give a low clucking call. Should one chance to see me before I call, it seems greatly startled and with head erect runs swiftly away, dodging behind stumps or other cover until far beyond reach. Pursuit at such times is useless as the birds travel rapidly under the thick cover where they may not be seen. As they walk about, the tail is held down but at short intervals is jerked over the back. Though they come within three or four feet of me in the heavy brush, I find it difficult to get pictures of them as they are always concealed by a screen of twigs. They are fairly fat and in good condition. The breeding season is at hand as males have enlarged testes and in some females the oviduct shows development. None seem to have laid as yet. The birds seem to have very limited ranges.

Tropicbirds circled overhead at intervals with harsh explosive calls and the white forms of Love Birds were constantly in sight. Frigatebirds soared easily often accompanied by Red-footed Boobies. Many of the latter, intent on mating, wheezed or clucked from perches in the trees. Noddies were always visible and Sooty Terns passed at frequent intervals. Rats were observed frequently among the bushes or running through the *Sesuvium*. Schlemmer and I returned along the outer beach and quenched our thirst from rain water held in such *Tridacna* shells as lay with the concave side up. The water from a shower at daybreak was sweet and fresh. I secured as much as half a glass from one shell.

Figure 38. Dr. C. Edmondson of the University of Hawaii packing corals at our camp on Wilkes Island, Wake Islands. August 3, 1923.

The beach conglomerate contains many corals and shells. Palmer made a collection of these fossils this morning. The sea came up in the evening to some extent and the wind shifted to southwest. Rain began in the evening as a light drizzle and continued for most of

the night. About midnight the wind died down completely to be followed by a few puffs of air. The sky to the south and southwest was heavily overcast and lightning came at times. Apparently it was high in air as the clap of thunder that followed was slow in coming. I was out at midnight, closed the front of the tent and put a guy rope on the front pole toward the wind. The surf seethed and roared without letup or cessation of noise during the entire night. Between twelve and one, four slight earth tremors lasting only a second or two each shook the island slightly.

August 4, Saturday

Was out at daybreak and found that I had caught a breaker full of water from a crude eave trough fastened on the tent fly of the skinning tent. Drizzling rain continued with a moderate breeze from the southwest. I was relieved to find the ship's dinghy, at anchor in our little bay, still in place. The sky was clear at the horizon in the east so that the first rays of the rising sun illuminated the storm clouds above us and to the south, tinging them with weird hues of copper, light green and olive, a strange effect, with a rainbow at one side. The whole suggested the appearance of some of the severe storms of the middle west. In a few minutes the light had disappeared, leaving the sky a dull gray relieved only by low drifting clouds. Here at Wake we seem to be only in the edge of the storm as the horizon to the north is clear. Rain stopped at nine and I went out and collected some terns that I needed to complete the series on Wilkes Island near camp.

The three islands that encircle the lagoon here at Wake have been designated as in the following crude sketch.

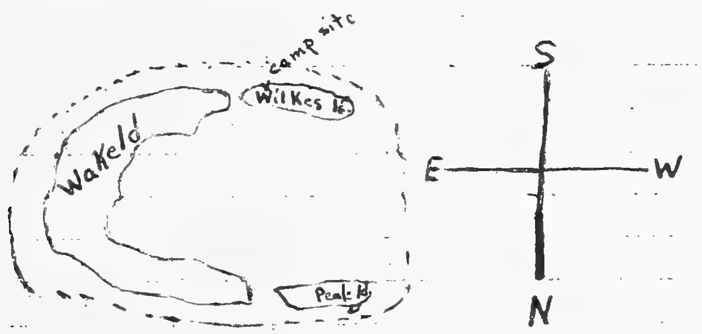

Figure 39. Sketch map of the Wake Islands from Wetmore's journal. Because Wetmore named both Wilkes and Peale islands, this is probably the first map ever made on which these names appear.

Specimens taken have been marked in accordance with this nomenclature. The rail does not occur on Wilkes Island. Otherwise the three seem quite similar.

Under Palmer's direction, a well eight feet deep has been dug at the highest point on Wilkes Island. The small amount of water in the bottom is saline. The walls of the excavation show a layer of rock mixed with humus to the depth of a foot, then a layer of sand mixed with coral lumps one to three inches in diameter to a depth of three feet, and then coarse lumps of coral, *Tridacna* shells and other large fragments up to 18 inches in diameter to five feet. The whole is bedded on a layer of fine-grained conglomerate, the old beach sand consolidated. Two other wells dug near the *Sesuvium* patch on Wake Island, at my suggestion, yielded salt water at three feet. The sand and other material is so coarse

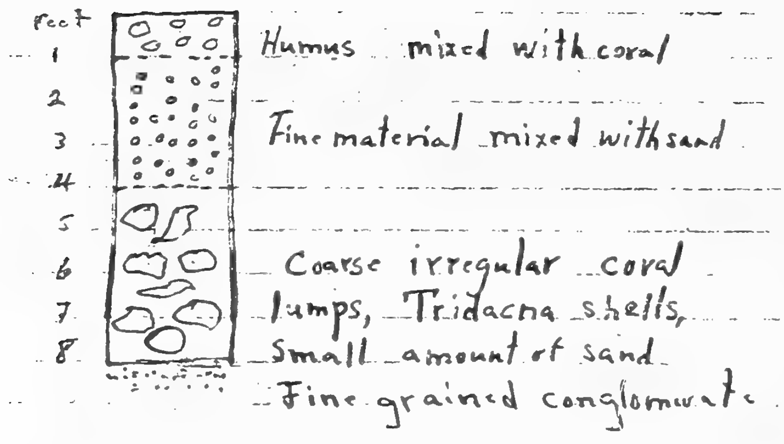

Figure 40. Sketch from Wetmore's journal of a section of sediments exposed in a well dug to a depth of eight feet on the highest point of Wilkes Island, Wake Islands.

that apparently salt water seeps through unchanged. It is possible that fresh water might be obtained in the finer soil at the eastern end of Peale Island. Dependence may be had on rain for a certain amount of drinking water.

Palmer and I cut a limb of *Tournefortia* two inches through on which I counted 12 growth rings of varying thicknesses. I was uncertain, however, as to whether these were annual or merely indicated rainy seasons, of which there may be more than one a year.

The afternoon was occupied with specimens and with packing. The sun came through at noon and dried things off. At night we gathered for an hour under my tent fly for an hour in friendly converse, our last night in camp. Peale records "*Diomedea brachyura*" with eggs here but I find no trace of a breeding colony nor have I seen any birds. (see Aug. 5, however) [added later].

August 5, Sunday

Clear and hot this forenoon. I was out at five and put my notes in shape and did some packing before breakfast. Later I visited the site of an old Japanese camp on the lagoon side of Wake Island near the channel separating that islet from Peale Island. A clinker-built boat 35 or 40 feet long that had been sawed straight through into three nearly equal parts lay partly buried rotting in the sand. English letters were indicated across the stern but the paint had scaled so as to make them illegible. Near at hand was a stone fireplace and a few upright sticks that had supported some form of shelter. Scattered about was the usual camp refuse--some broken bottles, chipped and broken bits of dishes of Japanese design and bits of metal. The camp apparently was eight or ten years old if not more[5]. It might appear that men had desired for some reason to conceal their boat and had to cut it to make it possible to draw it out of the water. It was hauled back among heavy bushes nearly 100 yards from the shore. [At the top of this page the following annotation was made much later: "3 weathered humeri, heads of 3 others and a tibio-tarsus [sic = tarsometatarsus], collected near this site on this day. 9/27/1968. These all are *Diomedea immutabilis*." See my notes in the species accounts.]

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[5]E. H. Bryan (1959:4) mentions copying a Japanese inscription inside the bunkhouse that "was translated to read something about leaving the island, with the date, November 13, 1908," which is about the same time as known Japanese poaching activity on Laysan and Lisianski.

Completed packing during the forenoon. Rise and fall of tide here 37 inches according to gauge. Daily temperature morning and evening 77° to 83° F. average 81° with intense heat at midday with thermometer at 90° to 95°. At noon showers began, so that we disembarked with canvas and outfit wet. The ship came close in and with two trips of the motor-sailer we were once more aboard. At 3:00 we were under way east for Honolulu.

Honolulu and Return

[August 6-12 at sea.]

August 13, Monday.

White-tailed Tropicbird this morning. Arrived Honolulu 4:30 p.m. registered at Blaisdell hotel.

August 14, Tuesday.

Disembarked outfit from TANAGER at ten went to Pearl Harbor with Commander King and saw Admiral John B. McDonald. Returned at noon. Lunch with Commander King. Work on correspondence and various details in afternoon.

August 15, Wednesday

At museum all day packing specimens.

August 16, Thursday

Packed and sealed alcoholic specimens today and finished general shipments to go by express. Eric Schlemmer's employment terminated this evening.

August 17, Friday

Worked on specimens at museum during entire day. Examined pertinent material for use in preparation of report. [Notes on various specimens in Bishop Museum.]

August 18, Saturday

Worked at museum all day again. [More specimen notes.] Bryan has types of *Telespiza ultima*.

August 19, Sunday

Went to Waialua this morning and visited Anderson. A fine trip around the island. Returned in evening.

August 20, Monday

[Worked at museum then went to opposite side of Oahu with Bruce Cartwright and Charles Judd. Went to Popoia Island and collected birds, set traps for rats, and returned after dark staying until after eleven.]

August 21, Tuesday

[Collected a few birds near Waimanalo, natural history notes, returned to Honolulu.]

August 22, Wednesday

Called this morning at the Pan-Pacific Union and met Dr. Bunker. Mr. Thrum called this morning and told me that his annual for 1879 was issued in December 1878. [This was of importance because this issue contained a paper on the birds of the Hawaiian archipelago by S. B. Dole in which several new taxa were named (see Olson, 1994).] Prepared and certified to expense accounts. Arranged steamship passage. This evening Palmer and Eric and I went to Pearl Harbor where Dickey's pictures were exhibited at the recreation hall at the submarine base. Fine film. Seats all crowded.

August 23, Thursday

Worked at museum all day today. Dickey's Laysan film exhibited this evening at the University Club to a large audience that included everyone from the governor on down. Very well received. I explained the birds to the audience. A wretched place to speak.

August 24, Friday

Completed packing this morning and went to the museum in the afternoon where I worked until seven in the evening. Located the type of *Micranous marcusi*.

August 25, Saturday

Sailed via the S. S. CITY OF LOS ANGELES at noon. Commander King, Ingham, Caum, Ball, Mann and many other friends down to see me off so that I departed well decorated with leis. 18 pieces of baggage.

[Arrived Los Angeles 1 September where met by the Dickeys and went to their home in Pasadena.] After dinner Mr. and Mrs. Law, A. B. Howell, and Loye Miller came in and we spent the evening viewing the Laysan film. [End of journal.]

Data from Max Schlemmer on Laysan and Other Islands.

[The following was inserted in Wetmore's journal between 29 and 30 April.]

In 1893 a small rat or mouse was reported so abundant on Lisianski as to be troublesome at night. None have been known in Laysan[6].

Diomedea immutabilis arrives at Laysan on the average on Oct. 25, the Black-footed Albatross usually a few days later.

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[6]This must be the source of Wetmore's (1925:104) assertion that there had been some kind of "rat" on Lisianski, although none was ever found by the TANAGER or any other scientific expedition. Schlemmer's information must have been derived from the experiences of John Cameron in 1893, who encountered myriads of mice (*Mus musculus*), the former presence of which has recently been confirmed by the discovery of bones (Olson and Ziegler, 1995).

The coconut trees on Laysan, planted in 1895, were secured from a schooner from Jaluit in the Marshall Islands.

See Morton, T., on Laysan -- A Bird Paradise, *Pearson's Magazine*, May, 1901, pp. 672-677, a popular article.

Pacific Commercial Advertiser, Honolulu, April 16, 1904, reports that on April 11, Capt. Niblack of the IROQUOIS found 17 Japanese in camp on Lisianski [See Clapp and Wirtz (1975:26)].

Bryan, W. A., Laysan Island, A Visit to Hawaii's Bird Reservation, *The Mid-Pacific Magazine*, Vol. 2, Oct., 1911, pp. 303-315.

Rabbits were introduced on Laysan Island in 1902-03. Animals were brought from Honolulu on 3 occasions but only 8 or 9 were sent out in all. [This seems a better first-hand source than any cited by Ely and Clapp (1973), where the earliest date of introduction was thought to be 1903.]

The following notes from Schlemmer's Journal [presumably all pertain to Laysan].

June 9, 1906. One Common Booby killed. First eggs of the big gray muttonbird [*Puffinus pacificus*] found.

Oct. 4, 1906. A duck supposed to be a hybrid between the Laysan Teal and the Spoonbill [Shoveler, *Anas clypeata*] taken. (Bird skinned and may have been sent to Schauinsland).

Oct. 17, 1906. Curlew and plover taken.

Oct. 19, 1906. One black goony [*Diomedea nigripes*] arrived.

Nov. 8, 1906. First albatross eggs found.

Nov. 10, 1906. Three albatross eggs found.

A "Chinese Crane" killed in winter of 1903 was skinned and sent to Schauinsland.

Gulls appear at times on Laysan Island. One skin may have been sent to Schauinsland.

On one occasion two or three *Procelsterna saxatilis* remained for several days on the rocks at the south end of the island. [Ely and Clapp (1973:228) mention only two sight records of this species on Laysan, in 1964 and 1967.]

8 different ducks are said to have been killed and sent to Schauinsland. [This was Hugo Schauinsland, once director of what is now the Übersees Museum in Bremen, whose book on Laysan is translated elsewhere in this volume. I have personally examined a few of the specimens of vagrant ducks from Laysan in the Bremen collections, which should be more carefully searched for some of the other specimens mentioned above.]

Small divers that must be grebes appear at times on the lagoon.

Two geese killed in 1915 were identified by W. A. Bryan as "Canadian Mountain Geese." Heads preserved and sent to Bryan.

A godwit [*Limosa lapponica*] was killed by Schlemmer.

[Also included in the TANAGER archives is a letter dated 6 May 1923 from Schlemmer's daughter, Terese, addressed to Wetmore in Honolulu.]

> Dad is quite busy at present but has asked me to write you a short message for him.
>
> There was an article in our daily paper saying no one know how the canary [= Laysan Finch *Telespiza cantans*] or rail or these small birds were put on Midway Island. At first Dad was going to inform the newspaper men but since you are at the head of the expedition he said he'd let you know. While at Laysan he sent the first rails and canary birds to Midway by Captain Niblack and others later by Captain Piltz.
>
> He also asked me to let you know that the two coconut trees on Laysan were planted there by him in 1895 and he said they have an interesting history that he might tell you sometime. (Came from Jaluit in the Marshall Ids!) [added by Wetmore].
>
> He also planted the "Hau Trees" on the Island a little later than the cocoanut trees.
>
> Dad asked me to inform you of these facts and also send his best wishes to you and hopes you are enjoying your trip and experiences on the Islands.

THE JOURNAL OF DONALD R. DICKEY

[Dickey, with his wife Florence, sailed from Wilmington, California, on the CITY OF LOS ANGELES at noon, Saturday, March 24, and arrived at Honolulu the following Saturday, March 31, on his 36th birthday, where he remained until the departure of the TANAGER. I have omitted those portions of the journal prior to departure for Laysan, except some observations on seabirds, particularly as they relate to the interpretation of plumages in the Black-footed Albatross, *Diomedea nigripes*, over which both Dickey and Wetmore puzzled considerably.]

March 25, Sunday

Thin fog Wind 4-6 (NW) Air 54°, Water 54°. Pacific Ocean sea rough NW Course 260°; Lat. 32°53'N, Long. 123°55. Average speed 12.6 (All readings daily at noon). Wandered out to the stern immediately after breakfast and found that the Western Gulls had deserted us during the night. Not one of the species remained. Their place had been taken by a flock that totalled 26 birds at its peak about 9:30 when refuse from the galley was thrown over. Six of these were Glaucous-winged Gulls. The other twenty stocky light-mantled birds were almost as certainly Herring Gulls.

About 11:00 a lone dark albatross hove in sight and I watched the marvel of its flight off and on till noon when it was joined by 2 more birds. They were unquestionably *Diomedea nigripes*. Several times they settled on the water in our wake and picked up morsels with up-raised wings and a petrel-like outline. This species is known to the sailors as the "dark (or "brown"---or "black") gooney." I have not heard them pronounce it "gony" as Fisher spells it in his 1902 Laysan report [= Fisher, 1906]. They differentiate it from the "light (or "white") gooney" which, they say never shows up till after we are half way across, and generally even nearer than that to the islands. They are surprised to see even the dark species so early in the trip---"generally not before the second or third day." Likewise they are quite certain they "are <u>not</u> albatrosses," being accustomed to the larger south Pacific birds.

March 28, Wednesday

High broken clouds and sun. Noon 68°---Water 66°. Strong SE to NW wind. Sea moderately rough. Lat. 27°49'N. Lon. 1+2°13'W [sic]. A <u>poor</u> day for most of the passengers but what a day for birds! The strong breeze of last night got up to perhaps 35 MPH in the night and half boxed the compass clock-wise---going around with the sun---so that by the time I went on deck this morning there was a nasty brown sea and a strong 20-25 mile wind.

The moment I looked astern I saw we had picked up a crowd of fellow mariners, for the blank air of yesterday was filled with wheeling albatrosses. All were *Diomedea nigripes*, but they varied so among themselves as to be intensely interesting to study from the plumage standpoint as well as flight. Heretofore we have seen only young birds of last year without the light rumps of maturity and with the white forehead and ring back of base of bill subdued or almost wanting. While birds in this plumage are still in the great majority there are a dozen or 15 birds with white rumps and bill rings of varying intensity. I have an impression that adequate material would show 3 or 4 annual stages to maturity. Either that, or the adults vary as tremendously in respect to the white rump as do the smaller white rumped petrels such as *O[ceanodroma] socorroensis*. By evening over 50 of the birds had collected about the stern of the ship wheeling within 15 to 20 yards of me in eager-eyed expectancy of a hand-out from the galley. Unpleasant as the day has been for

most of the passengers it has served to give me a feeling of intimate acquaintance with this dusky wanderer of the high seas.

April 4, Wednesday

Clear and calm---light NE trade. Our sailing day dawned clear and calm with only the usual clouds back over the Pali range and the light NE trade wind that guarantees fair weather. Went in town early with F[lorence] to get fruit and some last odds and ends and reported at the dock at 11:30 to stow the last gear below. Promptly at noon (12:05, to be exact) we got under way "in accordance with the verbal orders of Lt. Com. S. W. King, U.S.N., in command of the ornithological expedition to the islands to the westward of Oahu," leaving a little gathering on the pier in which I could see but one figure in white till we reached the harbor entrance and swung out to sea. This leaving folk by sea is an odd job and an unpleasant one.

Our party consists of Dr. Alexander Wetmore (in charge) and E. C. [=C. E.] Reno of the B[iological] S[urvey], Stanley C. Ball, David T. Fullaway, Edward L. Caum, David Thaanum, J. W. Thompson and Chapman Grant. The latter to my astonishment proves to be an old school mate at Thacher and goes just as handy man for Wetmore. He is now Major, 27th Inf. U.S.A., stationed at Fort Schofield, but has a keen love of natural history and wants to get back into the game. We also have Eric Schlemmer, a son of the Max Schlemmer, whose name is indelibly associated with the island of Laysan, as guano manager, rabbit importer, etc.! The boy goes as my camera assistant. We also have a cableman [A. J. Ker] reporting back to Midway from sick leave in Honolulu. He is an interesting New Zealander who has already put in one year on Midway and part of his second. He tells me that the Laysan Rail (*Porzanula palmeri*) and the Laysan Finch (*Telespiza cantans*) which were introduced on Midway have thriven so that both are now common on that island. This is lucky, for if the rabbit invasion has gone its logical course I fear for all the vegetation and in consequence for all the land species of birds on Laysan itself. Ker also tells me that the Hawaiian Seal (*Monachus schauinslandi*) is far from rare on Midway and that five were killed there in 1922 "for sport." One of the females was carrying a well-grown foetus. He thinks this was in February, 1922, and had the sailing of a certain ship---a rare thing on Midway---to cross-check his memory.

Of the naval force Lt. Com. S. W. King, U.S.N. has been specially detailed by Admiral Simpson for the trip. He was born of part Hawaiian blood in the islands, and has a fine record in the navy, so should be a distinct addition. Lt. Com. Talmadge Wilson has been similarly detailed as medical officer. He is a nut on fishing and has nearly as much tackle aboard as I have camera gear. In direct command of the ship itself is Ch. Bos'n Stephen Ingham (skipper) and Bos'n John D. Carroll (mate).

The TANAGER is ideally suited to our needs. She is one of the big ocean-going class commissioned in 1918 as mine sweepers. She and the LAPWING were the first of their class to see service in the rough work of "sweeping" in the North Sea. She is 187 feet overall by 35 feet beam and rates about 1000 tons. Civilian quarters below deck are necessarily cramped, with hammocks swung three deep in four tiers, but the officers have canvassed-in the top deck forward of the pilot house for our use---the anti-aircraft guns being dismounted for the purpose---and there I, for one, intend to eat, sleep and have my being unless we get into a wild blow. We are equipped with a whaleboat motor-sailer (launch), a dinghy and a self-bailer from the cutter service for our landing work. The navy is to handle the chow etc., exactly as for landing parties, sending a Filipino boy and colored cook, who are hashing out the chow for our table now, ashore at Laysan.

Running along in the lee of Oahu this afternoon is a good bit of all right---private yachting has nothing on this. 5:10 PM Sighted Kauai on our starboard bow from crowsnest. Ten minutes later we could all see it plainly. Rolled in early after a wonderful day enjoyed by everyone except Wetmore and Ker, and some of the crew who (Co. E. the "crew") had been on an *okolehau* [Hawaiian for a distilled spirit] jag the last night of shore leave. The long swell of the channel between Oahu and Kauai proved too much for them. I have dragged my air mattress upon "our" deck and am happy as a bug on the deck area where an anti-aircraft is usually mounted. Only three or four of the hardiest spirits, in addition to Schlemmer, who has sailed before the mast, and Ker have gone below decks to sleep, for we are battened down tight and the air is terrific down there.

April 5, Thursday

Clear, calm NE tradewind. Pacific Ocean en route to Laysan island. Meridian Position: Lat. 23°09', Long. 161°57'. Rolled out at 7:00 to find the old TANAGER rolls a bit in the full long swell of the Pacific, but she rides them like a gull and aside from actual discomfort of getting knocked about I imagine we'd do well in almost any weather even "top side" where we are most of us living. 9:05 sighted Nihoa on our port bow. This is one of the "high" volcanic islands sometimes known as Bird Island. 11:55 Nihoa on our port beam at a distance of 13.4 miles affording us a fine view of its rugged volcanic cliffs and sheer sea faces and ledges. It is no place to land a movie outfit, so I am just as glad this is a port of call for a later trip.

All morning (i.e. within 40 miles of Nihoa) birds have been increasing in numbers and particularly in species. Yesterday I noted only the everfaithful Black-footed Albatross and a few terns in the distance near Oahu, and a handful of lone "mutton birds" which we took for *P. cuneatus*, but this morning even by breakfast-time birds began appearing in numbers and in interesting species. Species noted, Wetmore concurring in case of two which I could not have sworn to myself: Black-footed gooney (Henshaw [1902], I notice, uses the "e" in "gooney"), 30 to 40; Red-tailed Tropicbird, few; booby (*S. leucogastra*), 2; Blue-faced Booby, several; Wedge-tailed Shearwater, common; Love Bird, few; Necker Island Tern---few; Gray-backed Tern---two; man-o-war bird---common. The latter all females or young males of last year hung above our masthead and occasionally seized our commission pennant inquisitively in their beaks.

12:30 Passed a motor sampan under sail heading east. 3:10 Nihoa out of sight, and with it went our birds, save only for our old faithful gooneys. A glorious calm day---rolled in at 8:00---on deck again, joined by one or two more of the men who could not stand the bed bugs that appear to thrive below decks.

April 6, Friday

Clear NE tradewind---sea moderate---rough. Meridian position Lat. 23°57', Long. 166°25'. Slept through but log shows we sighted "Necker Island on our port bow at 1:15 AM. 1:55 Necker abeam---distance about 7 miles." 8:50 AM Sighted French Frigate Shoals on our port bow and again our proximity to an island was shown by an increase in birds but in nothing like such a variety of species as yesterday---merely an increase in such standbys as Black-footed Albatross, man-o-war bird and Wedge-tailed Shearwater. However I did see my first Laysan Albatross and also what I took for a Christmas Island Shearwater at this point. 9:00 Stopped for repairs to valve stem of main circulating pump. 9:26 Went ahead part speed.

10:14 French Frigate Shoals abeam. This is a fascinating group of low sand spits encircled by a barrier reef with a glorious volcanic pinnacle rising to the southward where the barrier is incomplete. From our position half an hour ago it (the pinnacle) looks very like a schooner under sail and there seems some doubt as to whether it was named because of this resemblance or because they were discovered, or named at least, by a French navigator in command of two frigates. The sand spits are in some cases almost awash in the roaring surf that pounds even over the barrier reef, but two or three of them have all the Robinson Crusoe lure of sand slopes where seal haul out and great green turtles bask and laze.

11:45 Repairs executed. Bunch of porpoise this afternoon. Dr. Wilson missed a shot with a harpoon. We have seen several small schools, but this is the first one that has played about our bows in proverbial fashion. They sounded like a flash the instant the harpoon was hurled. Flying fish have been almost constantly in sight yesterday and today, but even so the sea seems more devoid of life than the Atlantic in similar latitudes. Grant suggests this is due to the lack of sargassum refuges for fry, etc. Dr. Wilson has kept a hand line and wooden bait out constantly but we have been making too fast time for fish to hit it. One or two have slashed the bait but failed to hit it squarely.

Wind and sea kicking us unpleasantly toward evening so that several of the boys have passed out completely and rolled in without dinner. Dinner time came and our cook showed up with a sheepish expression, a big platter of pork sandwiches and the terse remark, "Cook sick, Filipino sick, ah sick too!" With that he fled! I don't wonder, for I'd last about 5 minutes below deck. Grant and I polished off the last sandwiches and rolled in at 7:00 PM. Rough enough to be darn uncomfortable and even though one is not actively ill the solid deck to stretch out on is the pleasantest place and position.

April 7, Saturday

Calm and clear---NE tradewind---sea moderating. Lat. 25°14', Long. 170°33'30." The wind had almost died during the early morning hours, so everyone except Wetmore and Ker are happy again despite a considerable hangover in the way of a sea. We seem to be running out of even that, however. 9:15 AM Sighted "breakers l pt. on the starboard bow" from the crowsnest. Slowed to 2/3 speed ahead. 9:20 slowed to 1/3 speed ahead. 9:30 reversed course at 1/3 speed ahead searching for a pinnacle rock or coral head sighted by Wetmore a moment ago close in on our starboard side within a few yards of the ship and submerged only a fathom or so. The milky water and soundings show we are on a shelf projecting out from Maro and Dowsett Shoal five miles further than the chart indicates. We are still 10 miles or more off the breakers yet the lead shows less than 18 fathoms. Failed to locate pinnacle on the return---it's a big sea---so at 9:50 we resumed our course still at 1/3 speed. Breakers of the reef are now plainly visible even from the lower rail. They are lashing sky high in ugly white spume thanks to the fresh wind of yesterday. 10:12 Increased to 2/3 speed ahead. 11:30 Maro Reef breakers on starboard beam. The reef gives us lee enough so I have just indulged in my first shave. 1:30 PM Held "abandon ship" drill, manning the boats to which we were assigned this AM when we were pussy-footing around trying to locate Wetmore's pinnacle before it located us!

4:30 The look-out has just sighted Laysan due ahead of us. 4:40 Laysan appears as two bright fingers on the sky line---doubtless the 2 cocoanut trees. 5:50 West end of Laysan Island abeam. 6:10 Dropped anchor at the charted anchorage in 9 fathoms of water, with 60 fathoms of chain out on the starboard anchor. As we were slipping into the

anchorage Wilson had a strike from some immense fish that broke the wire lead line he was using and carried away his bait. The second supper was over everyone on board, it seemed, broke out fish lines and before long one of the crowd flopped a 3 foot sand shark over the side into the midst of about 30 whooping "jackies." Wild excitement. The sailors caught several more small sharks and ended up with a 230 pounder that Wilson had to harpoon to get on board. One of the sharks had an old corroded hook in its mouth such as the Japanese have copied from the ancient Hawaiian model for certain species of fish. It is barbless and shaped like this [sketch omitted]. One "ulua" was the only edible fish landed ---rest sharks.

April 8, Sunday

Calm, clear---NE tradewind---Sea smooth. Everyone was of course crazy to get ashore, so I let them practice their landing crews on the others' outfit and finally got my cameras and gear ashore about 10:30. Set up tent, which looks like T.R.'s outfit in Africa and after lunch set out to explore the island. Went south along the west shore to a rocky point at the south end where there are interesting rocks in which Hawaiian Terns are nesting by hundreds with 20 or 30 Love Terns and about 50 Gray-backed Terns.

One sees Laysan today with conflicting emotions. To one who has never seen the great sea bird colonies it remains one of the most remarkable of bird sights. By the time I got ashore the first bloom of the area about the houses had passed, for already the thieving finches had robbed many of the tern nests whose owners were frightened from the nest by the first landing parties. Even so, enough remained to give me a realization of how completely the birds hold sway here save only when man or man's introduced pests compete. To my surprise I found awaiting me the remains of 7 or 8 old shacks in various stages of collapse, and Schlemmer tells me there were even more when the guano gang of 50 or more Japanese was in full career. Before the main shack stand the two cocoanut trees that hold the record as being the only decent thing man has ever done for this island. In front (west) lies a charming circular cove with a narrow break in the reef through which we glided peacefully on this calm morning while the long swells pounded and broke on the reef a hundred yards each side of us. The break in the reef is so narrow, however, that I can imagine the landing would take trained men to negotiate in a brisk breeze even from the NE, and with the wind in any other quarter it would be impractical for cameras at least.

Even from the whaleboat I could make out the birds, but as it grounded and I jumped out on the glorious curving beach I began to make out the species which, as I said, have completely taken possession of the tumbledown settlement. The flat roof of a former cook shack is black with nesting Hawaiian Terns (*M. hawaiiensis*) which rise and settle back in only momentary surprise rather than alarm as the sailors pass with their loads of grub and duffel. Among them are 3 or 4 pairs of the gentle white Love Tern (*G. a. kittlitzi*) covering their lone egg on the rafters and plate sills of the old buildings without even one twig for a nest, just as they do in their more natural habitat where their egg is laid and balanced in even the slightest depression on top of the limbs of trees and bushes. The Hawaiian Terns build at least a semblance of a nest of seaweed etc. and crowd into close-packed nesting colonies. Two Laysan Albatrosses still held sway on the front porch while a ridiculous brown fuzzy youngster sat back on his heels and snapped his beak in childish threat as the crew worked too close to him. Red-footed Boobies, with a sprinkling of Hawaiian Terns, crowd every available nesting site in three bushes south of the buildings and make ludicrous threats with ruffled feathers, shrieks and bill thrusts at passers by. Luckily they stick to their nests until almost touched, for the finches (*T. cantans*) make short work of any egg.

The incubation was slight to nil in the broken booby eggs I saw. The windows and doors are all gone, and the sand has drifted 3 feet deep in the main buildings where the Schlemmer family used to live. But the house is far from empty. Wedge-tailed Shearwaters sit in pairs in every corner. Two pairs of Red-tailed Tropicbirds sit side by side on a drift of sand---taking the shade of the building's interior in lieu of bushes. A pair of finches are nesting behind the broken pane of an old window and stray individuals are hopping along the sills and rafters looking for any tern eggs that might by chance have escaped them during the flurry among the terns when the first boat landed. I fear they got them all in the main house which Wetmore is to use as laboratory. Luckily one Hawaiian and one Love Tern have hatched and the fuzzy youngsters are safe from the marauding finches. Outside birds are scattered everywhere, but not packed in colonies except in the case of the Red-footed Boobies and Hawaiian Terns. It is apparently only the overflow from the roof colony that are nesting in the bushes, cocoanut trees, lumber piles and main house. The finches hop about over the sand inspecting each new bit of duffel or grub that is lugged up from the boats, and seem utterly devoid of fear. Two Bristle-thighed Curlews stalk about behind the tents on the high bare sand ridge. Scattered <u>everywhere</u> are Wedge-tailed Shearwaters in pairs squatting at the burrow mouths. Apparently they are but just arrived for they sit side by side above ground or more rarely in the burrow. Most of the burrows are shallow as though but just begun. The tropicbirds, too, have not laid. The Hawaiian Terns of this colony have 90% eggs, 9% nests under construction and only a few young. Red-footed Booby fresh eggs. Finch ? Love Terns incubated eggs or young.

Yes, the birds are here at least in so far as the common sea fowl go but the striking thing is the <u>VEGETATION</u>---or utter lack of it, rather! Verily, the damned rabbits have done their worst. As far as I can see with the glasses and from our hurried trip down the island there is <u>not</u> <u>a</u> <u>living</u> <u>bush</u> <u>or twig</u> or <u>spear</u> of <u>grass</u> <u>left</u> on the whole island outside of the two poor cocoanut trees and the 3 bushes near the house that *Sula piscator* has preempted---and two of the latter are leafless! Apparently the swarming host of rabbits has gone the limit. The once green island is today a desolate sand waste that might as well be a salt sink in one of our barest sand deserts. In fact the salt lagoon which occupies the whole center of the island, and to which all the fringing ridges of sand slope down, gives the simile striking aptitude. In my wildest pessimism I had not feared such utter extirpation of every living plant. I had hoped that the rabbits had wrought their own destruction in the general ruin, but those who went east and north report two small patches of close-cropped "pickle" weed (*Sesuvium* sp?) that still support a remnant of the cursed host. The sailors killed them with stones and Reno with a rifle. In all probably 50 were accounted for.

Wetmore collected a pair of seals (*Monachus schauinslandi)* before I had the camera outfit "broken out" and ready for use. They were so tame that the female hardly bothered to wake up even when he shot the male close beside her. The male was dingy yellowish---the female a handsome mole gray. The sailors who were given shore leave got within 5 feet of another pair and put them to sea. I'm mourning the fact, for stupid as they are when once they have "hauled out" they are keen of scent according to Schlemmer and will not land where there is fresh man scent or disturbance.

Half a mile south of camp in another cove something like Camp Cove, we came on 5 of the big Green Turtles (*Chelone midas*) fast asleep on the sand. The largest would have gone well over 200 pounds. "Them ain't big ones" was Schlemmer's only reply to my interest in their bulk.

After lunch we broke out a camera and made a more extended reconnaissance to the south. Our turtles were gone, frightened and plagued by the sailors who are like a bunch

of wild kids out of school. Followed the high sand ridge down the west shore through scattered Laysan Albatrosses and thousands upon thousands of Wedge-tailed Shearwaters. The monotonous regularity with which one's foot breaks through apparently hard sand into their burrows of former years is exceedingly wearing on temper and legs. The south end is buttressed with sheer rock ledges ten to fifteen feet high of coral limestone. Against these the long rollers break in perpendicular spume. Since the prevailing fair wind (NE trade) is offshore it leaves a level dry rock ridge or dike. On the seaward side there are hollowed ledges that make fascinating natural shallow aquaria sometimes ten feet above high tide. On the land side is a rock-choked depression into which a pool of sea water surges through a hole under the dike. On the broken blocks just above the water of this gulch---hundreds, if not thousands, of Hawaiian Terns are nesting. Half of the nests contain a single lightly marked egg. Half are just building. Among them and also on top of the dike, almost in the spray of a powerful surge, Gray-backed Terns are beginning to lay their single egg on the bare rock or on the wave sand in depressions in the top of the dike. But best of all is the Love Tern, balancing its egg on the most astonishingly arrow ledges or even on top of pinnacles where any slightest movement would dislodge it. It would be interesting to see the parent roll an egg over in some of the more precarious sites. They lay a highly marked egg that for variety reminds me a bit of the eggs of Xantus Murrelet [*Endomychura hypoleuca*]. Add to their nesting interest the charm of their gentle personalities as they hang motionless and silent in the air peering---curiously at you within a dozen feet---add their fluttering dove-like flight, their immaculate plumage, soft black-rimmed eye and blue (basally) and black bill and it seems to me you have the most utterly charming sea bird I have ever met. There is no screaming reproach and no apparent alarm as you approach the "nest"---just a gentle curiosity. One of the boys even had one alight on his outstretched motionless fingers, so that by closing on its toes he actually caught and stroked it. Verily *Gygas* (misspelled attempt to perpetuate Ulysses' pilot?) should be the "Dove of Peace" emblem for the navies of the world. [The correct spelling is actually *Gygis*, and I have made the correction elsewhere. The generic name is supposedly based on Greek *guges*, a mythical bird mentioned by Dionysius (Jobling, 1991). I find no name similar to this in Anton's *Classical Dictionary* (1869, Harper Borthers, New York) that can be connected with the *Odessy*.]

The island is, according to the "Hawaiian Island Navigator"(?) one 3/4 mile long by 1 mile wide and 55 feet high, and contains a salt lagoon or lake in the center fully a mile long. We came back by way of this lagoon after circling the SE point of the island past a scattering of Black-footed gooneys. They are almost entirely wanting from the west, or lee, side of the island. Here I first saw the "dance" of this bird. I had heard so much of the "dance" of the Laysan bird that I was frankly surprised to find the brown bird doing fully as interesting monkey shines. In fact one pair of *nigripes* gave the best "song and dance" I have seen and heard yet.

Down by the SW corner of the lagoon we came on a stunted patch of tobacco run wild from an ancient Schlemmer planting. Here Laysan Albatrosses were more plentiful than on the high sandy ridges, but either the colonies have never recovered from the Japanese slaughter, or else they have scattered through what was formerly brush area and therefore seem scarcer. Certainly I have seen nothing to remotely approach in density the population of areas shown in old time photographs. The young, too, seem scarce in proportion to the adults.

Here the Man-o-war birds that are just mating on top of the bare SW ridge on the leafless foot-high stumps of former bushes are further advanced---many pairs having eggs

and almost all having nests. To my astonishment a turnstone (*A. interpres* [*oahuensis*][7]) rushed up to a ground nest vacated that second by a Man-o-war "Hawk" and pecked a hole in the fresh egg and began devouring it with evident relish. The dexterity and relish betokened long training.

Three or four pairs of Red-tailed Tropic Birds have eggs in this area and perhaps the same number of *Sula cyanops* are scattered about the flat incubating stained and apparently "hard-set" clutches of 2 eggs each. *S. piscator* had only one egg in the nests I saw.

The lagoon shore swarms with thousands of turnstones and Pacific Golden Plover. Imagine my delight when out from a dense swarm of these shorebirds waddled and swam a lone drake Laysan Teal---probably the rarest duck in the world, for this may well be the last survivor of the species. But while there is life there is hope. So far, we have not had a similar thrill or comfort by sight or sound of the rail, honey-eater or millerbirds. The rail I expected in the tobacco patch, but not a trace did we or anyone else get of it today. Luckily, Ker tells me, they (rail) are well established on Midway.

As we came back across the dry sand waste to camp we ran into a curlew feeding on a fish that had probably been dropped by a *Sula cyanops* as it ran the gauntlet of the Man-o-war bird colony. It seems striking to find this tender-billed shore bird turned scavenger and even cannibal, for some of the boys saw one devouring a tern's egg!

I found the body of a recently dead Bonin Island Petrel (*A. hypoleuca*) but no signs of it above ground. In the vast mass of Wedge-tailed Shearwaters scattered everywhere over the island we noted only a few dozen *P. nativitatis*. However, as evening approached they appeared in greater number near camp, so it may merely be that they are more nocturnal than *cuneatus*.

The rarity of the Red-tailed Tropicbirds worries me. Piecing together the dope of those who went in the other directions there seems hardly a dozen pairs on the island and the wild sailors have pulled the tail feathers out of half of those. It may be early, but since *P. rubricaudus* usually lays on the sand in the shade of bushes it may be that they have left for other islands to nest now that this is a glaring desert. Speaking of glare---the utter lack of green eye relief makes the drifted coral sand almost unbearable to the eyes---only my helmet is going to save me, for I fear I will not be able to judge light changes and focus with the dark glasses.

Looked in the rocks at south end and in the guano rock piles near the tobacco patch for *Bulweria* and *Oceanodroma* but without avail. I would expect them both to be late arrivals on the island. In the distance as we came home we saw a vast, hovering, circling crowd of thousands upon thousands of *Sterna fuliginosa* that act as though they had just arrived and had not yet settled.

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[7]The brackets are evidently Dickey's. He appears to have inserted this subspecific epithet as an afterthought and it is a curious refinement. The name *Tringa oahuensis* was bestowed on an example of a turnstone from Oahu by Andrew Bloxam in 1827, who did not recognize it as a European bird (Olson, 1996). The species is a long-distance Palearctic migrant and the name *oahuensis* has never, to my knowledge, had any currency as a valid subspecific name.

April 9, Monday

Cloudy early---sun. NE trade. Decided to do a good bit of scout work before getting down to brass tacks with the movie. Cloudy at dawn but by 9:00 it had broken away into the glare that seems typical under these NE trade conditions. Wilson, Wetmore, Reno and I struck out east and followed around the north end of the lagoon through the two damp patches where "pickle weed" is still clinging to life. Killed a few more rabbits. The remnant of the former host is necessarily congregated here. The Laysan Albatross also seem to like this green stuff and are thicker here than anywhere else on the island. Just beyond the larger patch NE of the lagoon the Sooty-backed Terns apparently intend to nest, but for the moment they are still a circling screaming undecided mass of whirling feathers and a babel of tongues.

Best of all was the sight of a flock of 11 Laysan Teal out waddling around in the pickle weed. They were never abundant---totalling perhaps 60 at their peak according to Schlemmer, so it is a delight to find they have survived the sanding-in of the old fresh water pond and the extirpation of nesting cover. We also saw a pair together in another part of the same damp patch. Finding the teal gave me renewed hope of finding the rail, for it would seem that he was better adapted to survive in the low matted pickle weed that is left in these two spots than any of the other endemic residents. But not a trace of rail or honeyeater or millerbird could we find. Finches were common among the rocks where the Sooty-backs are to nest, and also down among the albatrosses and shearwaters in the pickle weed patch.

Wetmore collected a Wandering Tattler from among the thousands of turnstones and plover. On the way back I saw a curlew break and eat a Gray-backed Tern egg and also saw another curlew run in behind us and smash a Blue-faced Booby egg a moment after we had unintentionally frightened the owner from her eggs. *S. cyanops* is more common at this end of the lagoon. We passed perhaps two dozen scattered nests. All were on the ground, of course, and those noted contained two eggs or 1 egg and 1 young. Apparently, from 6 or 8 new-born young and pipped eggs, the "colony" is beginning to hatch today with considerable uniformity. I quote colony because they are in no wise so gregarious as *S. piscator*. We have found no *piscator* nests except those crowded together in the one ironwood tree and 2 dead bushes near the houses.

My ear has got infected and will have to be incised, so I came aboard at noon in the belief Wilson was to follow immediately in the dinghy. However, he did not come off until the last boat so I am having to spend the night aboard. Wilson lanced ear down in "hospital room." I have never had a minor operation under less pleasant conditions than sitting on a box in a seaway down in the stink below decks while a navy surgeon cuts and carbolizes with raw acid! Now I shall have to sleep "below" for fear of catching cold in said ear. Got two square meals out of it at officers mess anyway!

April 10, Tuesday

Clear, high NE wind. Between the ear and the bed bugs I put in a second rate night in the foul air below decks, and was glad enough to roll out at 6:00. At 7:00 they put over the whaleboat and landed a work party of two men to finish shovelling the sand out of the main house where Wetmore and the Bishop crowd are to work. The wind and sea had come up during the night and it was wet tricky work getting from the Jacob's ladder to the whaleboat. I got off with only a stubbed toe, but Fullaway went sprawling head over heels and must have bruised himself considerably. Ball and Caum stayed aboard and about 9:00

the ship got under way to let Ball and Caum do some off shore "trawling and "dredging" for marine invertebrates etc.

Wind blowing so hard that movies in the open were out of the question, so Schlemmer and I went down to the protected hollow or "blow-hole" behind the natural dike at the south end and made a dozen plates or so. On the way back we ran into 5 turtles and made some film of Eric "rollin" them etc. They are helpless on their backs but the big ones are fiends to turn. (Hence I suppose "turn turtle.") Brought in a small one of perhaps 50 pounds to eat.

In making the tern stills the colony was so dense I had to sacrifice some of the eggs that were under or too near the tripod, by keeping the parents off the nest too long. Brought in 4 or 5 of the Love Tern eggs. Surf too high to land a boat this evening.

April, 11 Wednesday

Cloudy early---clear. NE wind. Cloudy till 9:00 so fooled about camp making some plates of a Red-tailed Tropic Bird that insists on coming into the kitchen and when not allowed to do that sits outside the door. Surf still breaking occasionally clear across the narrow channel, but about 8:30 they got out the whaleboat with all the jackies in life belts and came through easily enough, bringing Wilson ashore for the day and taking off the "work party" that were marooned here last night. Wind has dropped to the normal NE trade, so as soon as Wilson had dressed my ear Schlemmer and I started for the south end tern colony again.

The true Noddy (*Anous stolidus*) is present in considerable numbers, though much less common than *Micranous*, and is either a later nester, or else is disgusted with the lack of bushes it used to nest in. No signs of nesting or of even contemplating a colony site in any event.

Wilson went shark fishing in "Shark Hole" at NW corner of the island and caught 2 of the host that swarms there. These are a different species from the sand shark they are getting on board the ship, having a white-tipped dorsal fin and other specific if not generic differences. To noon today the crowd has accounted for 38 sharks.

But the danger of the island lies not in sharks but in the chance of stepping on one of the hundreds of rotten gooney eggs that litter the island everywhere but particularly in the vicinity of the lagoon where the nests may have been flooded out. At any event they have lain in this blistering sun since February and are in highly explosive and nauseous condition. One I measured was 4 1/8 inches by 2 1/16 inches. "Watch your step" is our motto. Yet Wetmore saw a curlew top one of these disgusting messes today and sip its stinking contents with evident gusto. This must be rare, however, for a number of gooney eggs near camp have been passed almost hourly by the dozen or more curlew that have set up as camp scavengers without being even eyed or molested. If they regularly ate gooney eggs the latter would have disappeared long since. Most of their thieving is probably restricted to the eggs of the Man-o-war bird as a maximum [size] and from that on down, with particular emphasis on tern eggs. It strikes me that the inability of the small birds to hide their nests from the persecution of the curlew, finch and turnstone under present bare and denuded condition may well be the actual cause of the extinction of the land birds. The prying eyes of these thieves cover every spot of the island and any sort of suggestion of a nest is an excuse for an immediate side trip of investigation. Once a nest was located the smaller land birds would be defenseless in the face of these powerful marauders. As I see

it the introduction of the rabbits was of course the primary basic cause of all of the island birds' troubles, but the consequent extirpation worked to my mind rather to prevent the small birds from perpetuating their species through lack of cover from bird bandits than to actually exterminate the adult individuals themselves. Reno's report of finding 3 specimens of *Himatione* alive and thriving today in the tobacco patch SW of the lagoon makes me all the more certain that the species could all have adapted themselves to the changed conditions and gained a livelihood had they only been granted nesting cover to guarantee new recruits to take the place of the older birds as they died off. This tiny Honey Eater was probably the most specialized in its feeding habits of all the endemic land birds on the island. God knows when the last flower bloomed on this barren waste. Yet here are at least 3 individuals of this specialized form persisting as a sort of heritage from the last nest of the species that was built in sufficient cover to survive. But, as it seems to me, old age and death now inevitably stalk this childless remnant of a vanishing species. [An accurate foreboding, as the last individuals disappeared in a sandstorm 12 days later.]

Wetmore took a Sanderling today---an island record, I believe. As the sun finally crashed through we shouldered the outfit and started back toward the tern colony at the south end of the island. Made some movie of a flock of noddy on the shore and a bit more turtle stuff. As we started home for lunch after working the terns, a bird attracted my attention floundering on the beach in the edge of the waves. When I got within 30 feet of it I realized that instead of being wounded it was a *Sula leucogaster* struggling with a squid that was a bit too big for it to handle. There could be no doubt as to diagnosis as I am familiar with the immature plumage of *S. cyanops*. There is simply no bird it could be confused with. Another island record.

It interests me to note the uniformity in size of all the young albatrosses of both species on the island and the seeming scarcity of young in comparison with adults. It can mean only one thing: that is a uniform laying season and then in addition an inability to "repeat" in case anything happens to that first prize egg. Those two things seem axiomatic---else we would see young of varying sizes, but such is strikingly not the case. The young of *D. nigripes* and *D. immutabilis* are superficially alike, but *nigripes* may be told by its heavier bill. At this stage, too, *immutabilis* young show the white of the juvenile plumage just starting if one parts the brown silky natal down, where as *nigripes* is of course brown clear to the skin even on breast and belly.

In shifting our cameras we had to disturb 5 Gray-backed Terns. To my surprise I found the idiots had not grown accustomed to the cameras even in the 2 hours we were away at noon. Although I fear they will be hard-baked I took the eggs to try and save them. Tonight the Man-o-war birds were out in front of camp robbing and mauling Wedge-tailed Shearwaters and boobies as they came in with their honest spoils. Boobies are so scarce on the island that shearwaters must furnish the bulk of *Fregata*'s toll.

April 12, Thursday

Clear. NE breeze. Back to the same tern colony to finish up with some High Speed stuff. Christmas Island Shearwaters are daily becoming more common. They are still only a drop in the bucket as compared with *cuneatus*, which I believe to be easily the most common bird on the island. Speaking of *P. cuneatus* Wetmore even went so far as to say he thought it outnumbered all the birds of all other species put together. I am not ready to say that, for the Sooty-backed Terns would in themselves make a vast host to offset, but his generalization certainly has a basis for its advancement.

Laysan Albatrosses are common but scattered. Terns swarm but only in local colonies, while Wedge-tails are common to abundant and are everywhere! Among them now, as I say, there is a sprinkling of *nativitatis* sufficient so that they no longer attract more than the most casual attention as they scramble out from under our very feet in an odd, indescribable, beetle-like scurry. The feet of these sea birds are all wholly inadequate to support them decently and the resultant gaits are laughable. The tropicbirds can not balance themselves at all, but buck and plow along on their breasts. However, they rise from the ground easily due, no doubt, to the fact that the wings have such a short beat-arc and descend so slightly below the shoulders at the bottom of the stroke. The shearwaters, as I say, have a low, horizontal, unbirdlike scramble like nothing so much as an overgrown beetle. The gooneys have a variety of bowery swaggers. The Man-o-war birds rise with difficulty and do not attempt to walk, and so it goes.

Finished up what film I want in slow motion of this particular tern colony this afternoon and lugged in the H.S., leaving only the Parvo and 5x7 to get some shots of the only juvenile Love Tern in the colony tomorrow when the early sun is on the nest. Five miles or more under heavy back packs in this heavy sand, broken with shearwater pitfalls is a mean day's work and I am dreading the two hours of film and plate changing before I can roll in.

Saw the biggest ear-wig of my life under a rock in the tern colony and got some for Fullaway. At supper tonight a Man-o-war bird actually seized, upset and knocked down into the water a bird I took at a distance to be *P. cuneatus*. There are so few boobies and so many hundreds or thousands of *Fregata* that the latter must prey chiefly on some other species, probably *cuneatus*. I had no idea how rough the darn things were with their unwilling hosts and purveyors.

Later---Schlemmer and the Filipino boy have just come in with 30 crawfish and an eel to show for 2 hours "jacking" and spearing on the reef, and the whaleboat with a "shore leave" gang has just put off with 75 more. As Wetmore says, "Any man who couldn't find food on this island would starve to death in a grocery store."

April 13, Friday

Clear. NE wind. Back a last time to the tern colony to get the morning light on the only Love Tern juvenile that has hatched. Remarkable propensity for clinging despite his webbed feet is probably a result of the arboreal life of the young. He grips your finger and balances and clambers about almost more nimbly than the young of perching birds. His home on a point of rock is only 4 feet or so above the tidal pool into which the water flows from a subterranean channel under the coral limestone dike. From his perch he can see swarms of little fry just suited to his needs. When it comes feeding time his gentle parent makes a 4 foot plunge from her (his) post beside the young and is back in the bat of an eye with a tiny shimmering morsel. The whole thing is utterly charming. The adults, as I have said, are beyond compare in their gentle grace and beauty. The eggs are the most variable and interesting of all terns I know. The young a silent alert brownish buff mite that is more active and capable than any tern of his age. The setting a rugged pinnacle that must seem a veritable eagle cliff to the youngster. And below him not 4 feet away the myriad life and tern food of a tidal pool to watch, and one day learn to catch! The famed albatross dance was a frank disappointment to me, but these Love Terns have fired my enthusiasm as almost no bird has ever done.

We snapped several stills of the youngster and made some film but unfortunately the sun left his perch in shadow before the parent decided we were harmless, and fluttered down from the rim of the "cliff" to give him the two tiny fish she had been holding for him for some time---holding cross-wise deep in the inner angle of the bill. All the other Love Terns save 2 in the colony about the houses have only eggs to date.

In view of the boat's [i.e. TANAGER] departure tomorrow I worked around camp this afternoon doing odds and ends that have been neglected in the excitement of work in a new area such as this. The colony of *Sula piscator* near the houses is doing pretty well---the birds sticking to their guns despite passersby. At 10 feet they merely make futile stabs at one or pay no attention whatever. As one approaches closer they give a terrifying squawk or scream and ruffle up fantastically.

There are perhaps 50 birds around camp in the ironwood "tree" and the 2 or 3 dead bushes. All of these save 3 are in normal adult plumage. Of the 3 exceptions one has almost attained full plumage lacking the coral red and blue (basally) bill and full rich red of the feet and the white of the back. Instead its bill is a purplish throughout---a sort of blend of the two colors which separate into distinct areas in the adult. The feet are a faded pinkish red and the back is marred by occasional gray feathers. This bird is the only one of the 3 which roosts with the nesting colony. It sits beside an incubating bird in the ironwood tree, but I have not yet seen it incubate so am not sure whether it is mated or not, though I am temporarily assuming this to be the case. The other two are gone most of the day and when they come in roost in the cocoanut trees instead of with the colony. These I am assuming are unmated immature birds. One has the full gray wings, gray back and pectoral band of the immature of last year. The other is half way between this bird and the subadult in plumage. The question is: Does it take more than one year to reach maturity or are these 3 birds cases of delayed moult? I should say from watching these 3 birds that it certainly takes them 2 years to attain full plumage and very possibly 3. All 3 immature birds have the unicolor purplish bill instead of the bicolor red and blue base-edging of maturity.

Wetmore took a female *Puffinus nativitatis* this morning with a fully formed egg in the oviduct ready to lay.

One thing I forgot to mention about my pet Love Terns. They are so gentle and moth-like instead of tern-like in their silence that it surprised me to see one of them give chase to a turnstone today that was invading the colony and drive him Hell-bent-for-election clear out of sight over the hill. These cursed little turnstones just live in the colony wandering from end to end of it watching for an unguarded egg.

As we sat at lunch there was a terrific crash and we looked out to see a surprised and sheepish Laysan Albatross picking himself up from the ground. Apparently he so far forgot himself and his aerial habit as to perch on a cocoanut frond, lost his balance and crashed 15 feet to the ground. To watch him waddle off, shaking his feathers into place and eyeing first one side or another of himself and then occasionally looking back exactly as though to see whether we had seen it all was so human as to be screamingly funny. Later in the afternoon a Laysan Albatross rose too high on his tiptoes to bugle at the end of his dance step, lost his balance and fell over on his back. It was several seconds before he could get rolled over and back on his feet and when he did the first thing he did was to look around exactly as though to say "who shoved me?" There is glorious comedy in these birds but it is so rare that the chance of getting the interesting things in the movie is nil. The best I can hope for is a bare record of outline and commonest movement and personality, and I

will not get that of all the species in the time allotted. I had thought of this light as ideal, but the wind blows night and day to ruffle feathers the wrong way etc., and even the light is less desirable than on the mainland. Ratty soft gray clouds scud before the trade wind and are forever banking up into dense masses just when you want to crank some interesting action. Then at midday the sun glares through with a tropical heat haze and a chalk and crayon effect that is worthless for the movies. And even if one wanted to use it the glare and heat almost instantly dope all activity out of the birds. By 3:30 or 4:00 when the birds begin to wake up, the sun drops behind a cloud bank again. It will be no sinecure---this trip---for results, but I wouldn't have missed the sight and experience for worlds.

Used up some bum (light struck??) film on the sailors packing the outfit down to the whaleboat. At 7:30 the boat came ashore for a last time and took off everyone save Ball, Thompson, Reno, Schlemmer, the cook and myself. They are due back for us the 28th or 29th. Photoed Wetmore's beard in front of booby colony the last thing this afternoon. He reserves rights of censorship.

April 14, Saturday

Cloudy-dull to bright. Strong NE wind. Boat [i.e. the TANAGER] left at 7:30 and by 8:00 we were marooned with no sail. Too cloudy---E[ric] and I around north shore---back across largest green patch 4 teal. Reno saw a rail here before we got there. On down to tobacco patch SW corner of lagoon. Brown gooneys all on windward side and as though to compensate young are in deeper holes---Dance finer both wings out---Laysan A. one wing.

Back to tobacco patch PM. Tropicbirds rare---must have shade to nest under. Only one in tobacco patch in shade of rock for morning sun. Took one Xmas [*Puffinus nativitatus*] egg. Boobies of both species present. I must have overlooked on 1st day---*piscator* as high as possible (1 foot)---*cyanops* on bare ground. Gray-backs small colony. Hawaiian Tern good colony---just building. Two or three pairs of Love Terns. Several hundred Black backs [= Sooty Terns] but no sign of eggs yet. No sign of Wedge-tailed Shearwater eggs yet a female bird taken had the largest egg 4 mm. Male bird also taken---mate. Made nest pictures---interesting place. Blew eggs---test developed---skinned two shearwaters. Reno saw rail.

April 15, Sunday

Trace of rain last night. Cloudy bright to dull. High NE wind hauling to E. A mere trace of rain several times during the night, with high wind continuing this morning and a constant cursed procession of gray cloud banks. Took the cameras and worked down the lagoon shore toward the tobacco patch at its SW corner but had more aggravation than success. Although I did get 200 feet of film in breaks between the cloud bank. A sudden gust smashed my glasses so I had a trip clear to camp to add to my discomfort.

The only real, bright spot was when we came on two of the almost extinct Laysan Honey Eater (*Himatione fraithii*), a charming little red mite of a thing that has well-nigh passed with the passing of the vegetation. This is the same place Reno saw his 3, so as far as we now know we were looking at 2 of the 3 last survivors. They had done their best to adapt themselves to the changed environment and were scrambling about among the rocks and on the guano earth picking up small flies. Their charming song is out of proportion to their size. Altogether they cheered my morning immensely, although their future can be

only extinction unless a more rapid restoration of the island can be effectual than I think possible.

Back to the "tobacco patch" SW of lagoon for whole afternoon. Continuation of aggravating cloud banks and moments of misty rain. Saw a single *Himatione* near the same rocks we found them in this morning. Crossed the sand ridge through scattering Laysan Albatrosses to the SE end of the island and made some surf film that I fear will be second rate. Back to the tobacco patch, amid the swarming host of *Sterna fuliginosa* that apparently intend nesting in the shade of the sparse green tobacco leaves. No eggs as yet and a female collected had no egg larger than 3 mm in ovary.

Several pairs of *Sula piscator* interested me. The mate seemed quite solicitous as to the welfare of the incubating bird and came to the nest at frequent intervals. Although the egg was in each case laid and incubation begun the returning bird in almost every case brought a green tobacco leaf as an offering. The incubating bird would take it and tuck it first on one side and then on the other of the nest rim with a great show of bustling activity.

The most interesting observation, however, might be termed "the parasite parasitized." The Man-o-war bird is the most notorious rogue, getting most of his living by robbing other species---notably *Sula* and *Puffinus*---of their booty when they come landward from their fishing. Even his nest material seems to be stolen in good measure from his neighbors' supply. He has been reported as even cannibalizing nestlings of his own species. Imagine my surprise, then to see a Bristle-thighed Curlew taking issue with a male Man-o-war bird <u>in</u> <u>the</u> <u>latter's</u> <u>nest</u> where he was incubating an egg! The curlew slipped up tactfully from behind and pecked and pecked and harried him time after time. The clumsy (on the nest or ground) Man-o-war bird would turn and fight back, but the nimbler curlew easily evaded him. Finally, after a particularly vicious and tantalizing assault, the Man-o-war bird forgot his precious charge and lumbered to wing. Instantly the curlew rushed forward to his prize and with one blow of his beak broke open the egg he had been after all this time and began to devour its contents. In an instant he was joined by 7 other curlew rushing to the feast and by 6 turnstones which tagged at the bigger brigands' heels. Afterwards we saw this perverted band systematically going over the colony for (some defenseless) tern with an egg, or for a larger bird that could be harried from its charge. Finally I succeeded in filming the same organized band in a similar attempt on another male Man-o-war bird. This time they failed in their purpose, seeming to lack the assistance of the perhaps now surfeited "shock troop" leader. Anyway this *Fregata* stuck to his post, and the ring of cunning thieves that had surrounded him gave it up as a bad job and trooped off to find an easier mark. Wetmore suggests this may be a method of supplying the lack of fresh water. Certain it is there is a high mortality among the shorebirds---particularly the Pacific Golden Plover, with the curlew mortality rating second. The plover seem to die with head and neck stretched straight ahead of them and flat to the ground just as Wetmore has noted other birds dying of alkali poisoning, so it seems almost certain that the extreme salinity of the lagoon, which froths up like Great Salt Lake into shore drifts of foam at the least lapping of waves, affect the plover adversely.

The whole mating cycle of *Fregata* is a fascinating thing I wish I had time to really study. Only a few of the hundreds upon hundreds of birds on the island have laid, so the males are at the height of their posturing and gular inflation. Apparently the male chooses the site for the nest, for in many cases I have seen a male posturing and imploring from some dead bush, stump or rock where later a nest would be started. Here, on the chosen site, he sits with pouch inflated to bursting, scanning the sky for passers by. When a bird of his species appears, the head is thrown back, bill pointed straight up, and wings thrown

forward until the primary tips lying on the ground in front of the bird make one certain the wing is dislocated. Finally a female descends beside him. This seems to be a signal for any other unmated birds to gather in until often an old male will be the center of an admiring or envious crowd of 5 or 6 females and males. Then the process of stealing a crude mass of sticks from their neighbors sets in. In this apparently sexes join, the theft always occurring on the wing by a quick snatch in full career. Then the egg arrives. Both sexes participate and both are often on the nest together. Still they may be surrounded by a crowd of other birds still, too, the male postures and inflates his pouch at passers by. Lastly there seems a sort of community nest which may be the home of the earlier circling crowd of younger males. Finding it impossible to steal his nest material they heap added material around the edges until sometimes 3 or 4 eggs will be laid on what is really one crude hit or miss platform.

April 16, Monday

Rain-trace cloudy. High NE wind. Cursed day of "grief." Awakened at 6:30 by sudden tropical gale and spit of rain. Tent pegs held, but before I could crawl out in my shirttail and cast the fly loose the gale caught it and ripped off the front portion. It has been my joy and delight---keeping film cool as a cucumber in temperatures ranging up to 89°. No great damage but a bad start. Black squall followed squall all day although the total precipitation would not exceed 1/10 inch Cloudy between times. Schlemmer skinned out some birds while I shaved, dressed ear, developed test and cursed. These lost days are getting on my nerve.

Certainly the birds do what they can to cheer me. As I sit writing at my table in tent a side [site?] and nest-hunting Red-tailed Tropic Bird is squawking the most horrible clucking squawks <u>in my tent and under my camp chair</u> just one foot from my foot. I just reached over and touched her glorious roseate back. On a camera box 4 feet from my nose a Laysan Finch is singing his heart out canary-fashion. He has been in the tent for over an hour, singing almost constantly. Beyond the corner of the tent fly, where it lies heaped on the ground a Bristle-thighed Curlew is picking idly at a brass grommet. So it goes---with no light to work them in. Skeletonized a curlew today and found the pincher claws of a fair-sized land crab in his stomach. It was emaciated and depauperate---who wouldn't be?

At 4:30 a Japanese sampan hove to in our cove---rugged devils, clear from Honolulu in their frail boat. Suddenly they seemed to spy our camp---<u>jibed</u> about and <u>flew</u> down wind. Probably opium runners or poachers with contraband aboard, who did not care to be investigated inside the 3-mile-limit. Both parties were equally surprised for we had not expected to see a mast before the 28th at earliest, and they had expected lee to ride out the nights rollers. A good thing, for they will spread the news the island is watched---even if it is only once in 10 years. Reno brought in a desiccated Laysan Rail tonight---dead not over a month.

April 17, Tuesday

Showers. Wind gentle. Cloudy except 2 hours. Misting. Another aggravating day with humidity that frightens me---100% tonight! Sharp showers in night but before we got to work in the tobacco patch colony it had clouded over again and was misting spasmodically---"liquid sunshine," Hell! Waited around all morning for 1/2 hr of sun.

To kill time I set out looking for petrels as we used to on the Coronados, none having been detected to date on the island. In 5 minutes I had 5 which I take to be

Bulweria bulwerii located in crevices in the piles of guano rock SW of the lagoon, in just such sites as *O[ceanodroma] melania* would choose if it were present on the island. Took two for myself and two for the Biological Survey. Wetmore will be able to get all he wants on his return as they seem common enough in the restricted spots that are suitable for them. Found a poor emaciated Laysan Albatross dying from lack of food due to a broken wing, so put it out of misery with a pellet of cotton and ether in throat and skeletonized it. Had an hour or two of fair to fine sun in afternoon and should have some fair film of the Sooty-backed Tern colony, Man-o-war birds, etc., about the tobacco patch.

The pair of *Himatione* are about the same rocks today, but so far I have not succeeded in photographing them. The noddies at last are showing nesting interest. Several pairs are hanging around the low broken guano rocks in the same section. As soon as one comes to know the birds there is as much difference as between day and night between noddies and Hawaiian Terns. The former is larger, more pigeon-like, lighter in coloration, heavier and stumpier in bill and has a coarser lower-pitched and entirely different note.

Saw something I would not have believed possible this afternoon. A Bristle-thighed Curlew stepped into a Man-o-war bird's nest which was left unguarded for a moment, picked up the egg in its long decurved bill, and carried it 15 feet, dropped it, broke it open and ate it! Got some film of it but had no time to set diaphragm so it may be hopelessly overexposed. At least it will be a record of fact. These cursed bandits must have accounted for every egg, save 2 or 3 that have hatched in the rock colony of 100 pairs of Hawaiian Terns that are now sitting disconsolate on old empty nests on these rocks---only 2 or 3 pathetic young to show for the whole colony's first attempt. Now some of them are starting anew out on some lower rocks which the noddies were inspecting and where the Curlew will have an even easier chance. Only the Sooty-backs seem fairly safe from them. They nest in close-packed masses of thousands upon thousands of birds each just pecking distance from its neighbors. A curlew in the center of that throng would be pecked and pestered out of the colony. The only danger to them would be from man or some other agency scaring off the incubating birds, for of course the outskirts of the colony would be picketed with bandits.

Killed a rabbit on way home. It ran 100 yards after we started it first and hid behind a young gooney. Schlemmer slipped up and grabbed it. They are getting rare, but it would be hopeless to try to exterminate them. Reno is not even trying to use his 17 bales of alfalfa to poison them. Birds just use it for nests and rabbits are too scattered. But with a couple of hundred thousand holes to hide in and a readiness to become nocturnal in the face of pursuit there is small hope of getting them all. It is pathetic to see all the tiny green leaves make a last scattering try now that the rabbits are so reduced. Last night Reno got none. Night before 1 female carrying 11 young. No wonder they peopled the island!

April 18, Wednesday

Rain at dawn, sun till 11:00, cloudy. Light SE wind. Ball, excited by the *Bulweria* I brought in last night, went petrel hunting with a flashlight in the evening and found a pair of the birds under one of the old shacks. I went down with him and was interested in their "barking." While we had the light on them one of them began to "make up to" its side partner, and in doing so gave vent to a series of low explosive barks that would have passed as the distant welcome of a 20-year old family bull dog. Oddly enough the Christmas Island Shearwater begins its song with just such explosive "barks" before settling into the cat-like yowling that indicates its kinship with *P. cuneatus*. In other words

its voice is a composite of *B. bulwerii* and *P. cuneatus* just as its body size is intermediate and just as it combines the color of the petrel with the other characters of the shearwater.

But the voice of *P. cuneatus* is the one that will stick in all our minds as the oddest and constant bird note of the island. All night a dozen are yowling and moaning at once about your feet wherever you go, and even by day the low moans come up from the nether regions of the burrows or break into the wild climax that accompanies a fight. It starts as a low "moan," as everyone else has called it, that to me seems from the first more cat-like than human---more of a potential yowl than a moan. There is a crescendo and climax even in this low conversational stuff followed often by a change of timbre, as though the last of the wail was an inhalation. This as I say is a continuous chorus from a full 100,000 throats all night. Of these a dozen will be near enough to definitely obtrude themselves upon your consciousness until one grows accustomed to it all. In the distance where the quality is softened it keeps reminding me of the chorus from a pigeon cote. But when 2 males (assumption) take a fancy to the same burrow or female the notes rise into a pandemonium of cat-calls, screeches and yowls that no one could grow accustomed to any more than to a caterwauling party on the back fence when one wants to sleep. In fact the sound of these rough and tumble fights so exactly resembles a cat fracas as to be laughable. The ensemble emitted by a mating party of about 9 erotic cats exactly describes the racket. These rough and tumble fights are very real affairs. They occur mostly at night yet no day goes by without my seeing at least one. They roll over and over with first one and then another on top and with bills grabbing like bull dogs at wings, legs, feet, or necks. I can imagine serious injury sometimes resulting. It would be a scream in the movies, but though they sometimes last for some minutes they are usually over in a few seconds and, as I say, are mostly at night or before I could set up the movie. Last night they undertook to undermine one corner of my tent and evidently there was "a triangle," for every 5 feet it seemed they would knock off work and screech their fool heads off. Theirs is the most versatile and ubiquitous vocalization.

The voices of terns are of course the same the world over, so I was surprised at the diversity in the 5 species here. The Gray-backs have an iterated triple cry or rasp, "kay-tee-did" run quickly together with the stress on the second highest pitched note. Sometimes it reminds me of the old high school whistle, rasped out, "T-O-E." The Black-backs [Sooty Terns] I have heard only screeching in clouds of thousands, but I imagine the constant voices in the air at night are largely theirs. "T-O-E" would be better for them with the stress on the first note. They sit on their chosen nesting grounds all day, or hover screaming above it so much of their activity is doubtless at night. The Love Terns have a gentle wheezy twittering like an overgrown Cliff Swallow [*Hirundo pyrrhonota*] The Noddy a long low pitched grating. The Hawaiian Tern [left blank].

To revert: camp is a full half mile from the big Sooty-backed Tern colony NE of the lagoon. That is none too far. Night and day, even here, the rasp is noticeable, but distance makes it seem more like a frog chorus in the distance. It interests me to see how constant it is. When undisturbed by man the thousands upon thousands suffice to insure that at least part of the colony will be in an uproar, and the Babel rises and falls but little and is never still.

The albatrosses in general are silent birds, but in their "dance" they emit a like "whee," more like a shorebird note than such a great bird's call. Also they have the stifled "trumpet" or "moos" as someone calls it, at the end of the dance when the head is raised. It always sounds as though the position stifled it---it is so muffled. Only the Black-feet, when they get to lashing their heads sideways in the ecstasy of their dance put any

animation into the calls. Then their "whee" grows to an excited crescendo climax that satisfies the listener the bird's heart is in it. Most of the Laysan dances I have seen are stodgy affairs of curtsying and bill snapping. The Black-feet are better all around, throwing out both wings instead of tucking the head under one and putting more pep into it.

The harshest note of the island is the terrible screeching cackle of the Tropicbird. The Sulas I imagine are purely diurnal, as the immature birds I spoke of before always come home at sundown to perch in the cocoanut trees and peer down stupidly at the light of our flashlights. *Diomedea* seems stupid at night and generally both parents will be found lying near their youngster with the head under the feathers of the back. The Man-o-war birds seem also to come home to roost at night, the foot-high stumps of dead tobacco plants on the west side of the lagoon being black with them at dawn.

Found a Bristle-thighed Curlew dead today in the tobacco patch where we spent the day---mostly waiting for sun. Too far gone to save, so skeletonized it, hardened drops of egg yolk from her last breakfast clinging to her neck feathers. As I walked along the edge of the Sooty-backed Tern colony a dead Gray-back caught my eye. As I picked it up it gave a few gasps but it was so completely all-in that I put it out of its final agony. Skinned it myself instead of trusting it to Schlemmer, whom I'm trying to teach to skin, and found it had died in oviposition, an egg being lodged at the orifice of the oviduct. Doubtless she had been in labor all day if not longer. Stomach entirely empty and general appearance of viscera suggested that she might have gone without food for two or three days. There are a dozen pairs or so that have sought the shelter of the great Sooty-back colony. Unfortunately they are on the outskirts, so still subject to the attacks of the curlew. The last solitary youngster was gone from the Hawaiian Tern colony this morning. The whole effort of this colony of a hundred pairs or so has been fruitless. *Fregata* probably got this juvenile. In all there are about 25 Love Terns scattered through these broken guano rocks---40 or so at the south end of the island---15 or 20 about camp---in all fully 100 birds on the island.

Another beastly day of waiting for sun but made memorable by a bit of luck before lunch that I will never forget. I saw finches (*T. cantans*) hop on a certain rock twice in quick succession yesterday so guessed it was a regular vantage point. Set up the camera and soon had a Laysan Finch recorded on the film (if all goes well and this cursed <u>100</u> % humidity does not wreck me.) As I finished, I heard a weak but charming song behind me and whirled to find one of our pair of Laysan Honey Eaters singing his heart out for me. Whirled the camera, slammed the focus lever, cranked and think I have him And before I had recorded the footage and "shot" Schlemmer came up holding a Laysan Rail in his hand. To get all the footage possible we turned him loose in front of the high speed. Meantime I had held alive and unhurt in my hand one of the two Laysan Rails we know are left on the island, noted his red iris and green (basally) bill and depauperate wings, developed plumage. To think of getting one of the 3 Honeyeaters we know to be alive and one of the 2 Rails and one of the Finches in lightning succession was indeed luck. To compensate a lever on the high speed broke that is irreparable in the field. I can get by, but it will add difficulties to the already grilling it is game for the rest of the trip.

Wetmore thought perhaps this egg-robbing debauchery was to get water, but an experiment today would seem to argue against such a hypothesis. I found a pecked tern's egg (*S. lunata*) that could not hatch so used it in an experiment. Put it on top of the finches' rock and soon one had it drilled throwing the shell chips to right and left. I then took the egg away from him, broke it and poured the water "white" in the same depression

the egg had rested in. Instantly the Finch returned, looked sadly disappointed and hopped away. I then put the yolk in a nearby depression and when I left there were three birds fighting for that like English Sparrows in the gutter. They are simply after the protein and fat food of the yolk, to my mind, and not after a substitute for water. Much as they would doubtless like it if a satisfactory substitute for water were easily procurable in this waste, it does not appear to me that eggs furnish that substitute.

Figure 41. One of the last three individuals of the Laysan Apapane *Himatione sanguinea freethii*, perched on a piece of coral rock. Photograph by Donald R. Dickey, probably taken from the movie made by Dickey on 18 April.

April 19, Thursday

Calm S wind. [Nothing else written].

April 20, Friday

Wind SW veering to NE 77°. Surf rolling high tonight.

April 21, Saturday

Cloudy, highest surf. [Some very abbreviated and mostly indecipherable notes on birds omitted.]

April 21, Sunday

Shower in night. Calm, clear perfect day. Gentle E breeze, mist---calmest moment of trip air SE. Everything comes to him who waits, even though he wait as ungraciously

as I have through the last profane ten days. Awoke to a calm bright morning---the first of the trip---and except for a dark cloud that formed and whirled in one spot over the island for 2 or 3 hours, it remained fine all day. Almost incredible! Up and at it early, packing Parvo, High speed and graflex over to the "marsh."

23 April, Monday

Rain and mist---driving N gale---clearing to sandstorm in afternoon. Hell of a day. "And now I must pay for my fun!" Awoke to the shattering tune of the tent straining at every peg before a driving north wind and soaking mist. All my preparations for a big photographic day---preparations over which I worked till 12:30 this morning---went for naught. Cursed the Sahara of Laysan and decided to declare it Sunday. About 10:00 the driving mist let up so we (Reno, Schlemmer and I) decided to walk around the lagoon. Saw 15 Laysan Teal all in sight at one time, and Ball afterward reported 18 when he passed them earlier---they are paired off now, but congregate at some small holes NE of the lagoon which seem to hold the rain water in less brackish form than elsewhere. The finches are common about these same holes. The males are wearing into the full yellow plumage and the boys have reported seeing them carrying nesting material into crannies in the guano rocks.

Checked up carefully on 109 *Diomedea nigripes* on our way around the island. One had considerable white on crissum with faint indication of light feathers on rump, but no suggestion of a true rump patch. Another had scattered light feathers on crissum---none on rump. All the rest were unicolor posteriorly. I am at a loss to account for the birds I saw on shipboard with the full white rumps. I had assumed that they were simply in the plumage of full maturity, and that those with less white were grading down in age---or at least in degree of high plumage---to the unicolor (in rump and crissum) immatures. Yet here I am on one of their great breeding grounds and yet I can find no single individual with a real rump patch, and 98 to 99 out of 100 exhibit no tendency, even, to white on either crissum and (even less) rump.

Ball has an ornithological find to his credit today. A pair of *Sula leucogaster* are nesting on the ground among the rocks NE of the lagoon. This neatly vindicates my first sight record for the island. (cf. 4-11-23)

Southeast of the lagoon there is a glorious Man-o-war bird colony that should be filmed, but time slips by under the curse of days wasted by wind and cloud, gale and mist, until I despair of covering half that should be done. With even 50% of working weather I could have made a clean-up, but except for yesterday it is rare to get an hour of working weather a day and day after day has been an utter blank like today---in fact a blankety-blank! For when we got over east of the lagoon it came on to rain---driving horizontally in a fine spray that soon soaked us to the skin and chilled us to the bone despite the fact the thermometer showed 68° at noon when we got to camp.

Southeast of the lagoon is one small (6' x 8' x 10') wind-sculptured phosphate rock in which an interesting colony was nesting. Just a glance with rain-blinded eyes showed several pairs of *Bulweria*, 1 *Phaethon*, 2 *Gygis*, several *Puffinus* around the base and atop the whole, spying for eggs, a *Numenius*.

Picked up a Golden Plover for a skeleton. It was dying probably of the alkaline or saline poisoning that affects this species particularly of the various shorebirds here, and had already keeled over on its side, too weak to face the wind when I picked it up. Died almost

instantly---the fright being apparently the last straw---more emaciated than I believed anything could be and live.

This afternoon the clouds broke at times, but the gale increased until the whole island seemed to be walking---a regular cursed sandstorm of the worst sort. Thank heaven for my floored and almost air tight tent. The rest have an eighth of an inch of fine dust and grit over everything. Outside every trail is obliterated---the sand is crawling in new-made ripples---every *Puffinus*' hole is filled or filling---the poor seeds that had sprouted bravely after the rabbits were thinned down are being blown out of the ground---or the ground blown away from them. Off the south end of the island flaps a regular sand "banner." Life is Hell!

Figure 42. Stanley C. Ball on Laysan Island. Photograph by Donald R. Dickey.

At 4:00 a sampan appeared off to the east of the island rushing along under full sail, passed south of us and made off WSW. This afternoon Schlemmer picked up a bottle dropped from the U.S. A(rmy) T(ransport) "Logan" in Lat. [left blank] Long. [left blank] on requesting finder to return same with report to U.S. Hydrographic [left blank] office. The old wrecked sampan on the north shore was No. 20, Honolulu listing, as evidenced by one of the battered blue boards. Such are the data one must piece together to write the story of the sea---to Hell with it and its islands, is the way I feel tonight.

Tried scrambled Man-o-war bird egg tonight. It was doubtless nourishing, but I did not relish my share. A gentle pair of *Bulweria* have taken to spending the nights in the kitchen arriving, according to George at dark the last three nights and leaving about 5:00 AM.

April 24, Tuesday

Cloudy. North gale---sandstorm. Hell of a day. The gale and blinding sandstorm continues unabated and life in the open or in the tents or tumble-down shacks is equally unbearable. Not much sleep for anyone, but luckily my tent has held so far, by turning the fly loose. The other boys were up off-and-on replacing pulled pegs. Life is plain hell, with grit in food, eyes and everything. I hate to think of the outfit repairs that will be necessary.

Everyone except smiling George, the cook, is on edge. Took Eric and plowed out into the stinging blast of sand to observe conditions with the birds. There is not a shearwater burrow entrance visible on the higher sand ridges and the island seems almost deserted of birds. A Man-o-war colony that had a dozen eggs yesterday and another dozen mated couples is deserted except for one male and one female that are sticking to their eggs. The rest have given it up and taken to the air leaving a feast for the curlew.

The young albatrosses are facing it out alone with heads low and out ahead of them into the wind instead of under the wing or down of the back as they generally sleep away the days. Their eyes are running with tears and in each corner is a pellet of sand accumulation. Rescued 3 or 4 that had backed into the mouths of shearwater holes and literally been buried alive. One whose head and neck alone showed was almost too weak to sit up and face the wind when I rescued him. All the shearwaters that sit around by thousands above ground have taken to the sea except an occasional bird or pair that squat blinking the nictitating membrane in an effort to throw out the sand from their eyes.

Collected a pair of *Sula cyanops* and found the male was the bird that was incubating perhaps indicating that the males do the incubating by day. Reno took a bird that further bore this out, but of course full data of many cases would be necessary to eliminate coincidence. They make no pretense of a nest but lay the eggs (2 in all but 3 or 4 cases out of 40 or 50 nests examined) on bare sand in the center of a circle which they keep brushed free from loose sand by rotating about on the axis of the eggs. A few of the young are two weeks old, many just hatching and perhaps half still have eggs. Irides bright yellow.

Went over to the big marsh NE of the lagoon after lunch to see how our cache of tripods, etc, had weathered the storm, but found the cache buried in sand and did not dare remove covering to examine damage in this gale. No sign of the teal today. Laysan Albatrosses have gathered from all parts of the island to the marsh, where sand does not blow in their eyes. The pair of *Sula leucogaster* Ball found is incubating 2 eggs on a nest of dry *Sesuvium* stems on the ground on the edge of a scattered colony of *S. cyanops*. In every way they resemble *S. cyanops* with a black stocking pulled over head and neck. Feet greenish. Irides [blank]. The nest was on the ground in just such a situation as *S. cyanops* but differs from latter's in being built into at least a semblance of a platform. Apparently just this one pair on the island.

Took four Man-o-war birds from a colony among the rocks. They seemed loath to take to the air from their sheltered nook and allowed us to pick them off the nest. Took a

male, female and immature female in the white-headed, brown throated plumage of immature. Also took another female for a skeleton. Picked up an injured *Sterna lunata* and will make a skin of it. Schlemmer sneaked up on a curlew asleep in shelter of a rock and picked him up in his hands. In fact all birds collected today have been picked up with only a bare, or at most gloved, hand for weapon, and then etherized. No signs of storm's abating this evening---cannot see half a mile in any direction on the island.

April 25, Wednesday

Broken clouds---NNE gale---sandstorm (third day) hell on earth. The terrific cold gale and sandstorm continues unabated---almost unbearable---getting on our nerves---third day however, wind a trifle E of N and scudding clouds broken with moments of sun, so we pray to heaven it may go down with the sun tonight. Outside sand cuts face like a knife. Am keeping the tent sealed tight but even so there is grit in everything. I hate to think of the condition the movie gears will be in! Huddled in a corner of the shacks and finished skinning the birds collected yesterday. Got out for half hour after lunch to collect few more birds. No sign of let-up tonight but sharp rain squalls are laying the sand.

April 26, Thursday

N gale unabated---rain squalls---less sand blowing---hell continued. Fourth day and night show no abatement of the N gale and driving sandstorm. I have had many camps but none so continuously unpleasant as this for two weeks. Nor does the fact that it is my one chance at these islands and that the storms have cost me at least $50 a day in dead loss for two weeks add to my cheer. However, the tent has held, God knows how, and we have had the shelter of the old shacks so we could prepare hot food and eat in comfort. All in a lifetime. Wind more puffy tonight---clouds more broken and wind a few points E of N.

27 April, Friday

High NE wind---broken clouds---gale abating---heavy rain at 9 PM. Still blowing but tomorrow or next day the ship is supposed to come, so we tackled it anyway, going over to the big marsh NE of the lagoon again.

Saw curlew tackle a few Gray-backed Terns nesting among the rocks---kept pestering till it got a bird off its egg. Then despite the defense of four terns it proceeded to eat the egg, showing that they simply haven't punch enough to bother a curlew. They drove at him to the best of their ability and one even seized it by the skin or feathers of the neck and bodily yank him away from the egg, but he simply turned back to his repast. It was so crude and the terns defense so pathetically futile, that Eric seized a rock and killed him at his feast. The terns hate and fear the curlew and even go far out of their way to try and drive them off, but the cursed little turnstones, and to a lesser degree plover, peck and spy right among the terns without arousing their suspicions---yet they are quicker even than curlew in their deviltry if there is a chance to sneak in and whack an egg open. They work their deviltry by slyness---curlew by straight bluff and pugnacity.

The Sooty-backed Terns have finally settled on the NE corner of the *Sesuvium* patch and have at last begun to lay. There are perhaps 20 eggs out of the thousands of pairs. By working with extreme caution we got up within close striking range of the Laysan Teal. 14 were in sight at once---all of them in pairs but keeping in a loose flock squatting in the *Sesuvium* weathering out the wind with heads tucked under their back

feathers. When 2 pairs walked past each other the males jumped at each other with the most ludicrous show of threat. Saw Plover actually tapping egg again. Vile day to have to work but we got something done in spite of wind, blowing sand and broken clouds.

Saw my first specimen on the island of *D. nigripes* with the full white rump and crissum such as I saw from the ship, so assume it is merely a phase proposition which chances to be rarer on Laysan than elsewhere, to judge by the relative abundance of the bicolor type seen at sea. Or it may be a matter of extreme age, but certainly not a matter of mere maturity as stated in Bailey, and no doubt, in Ridgway. [I don't know to what the Bailey reference may be. A. M. Bailey was on Laysan Island in 1912 but did not publish any observations until long after the TANAGER Expedition. The other reference may be to Ridgway's *Manual of North American Birds*, as his larger publication on *Birds of North and Middle America* was never completed and did not cover albatrosses.]

April 28, Saturday

Heavy rain at 1:00 AM, 8:00, and 4:00 PM. Clear 9 to 4---fine clouds---east wind. At last the wind dropped after the worst wind siege I have ever experienced, but only to veer to the east and bring up the first prolonged torrential downpour we have had. The first came at 9:30 last night, but the heaviest downpour came between 12 and 1:00 AM. When I finally finished rewinding and loading plates and turned in it was still pouring. Another heavy rain at 8:00 AM. We could have caught a cistern full of water had we had a cistern instead of pans and pots and coal-oil cans. By 9:00 it had cleared gloriously with the second collection of decent clouds for photography we have had on the island. Rushed post haste for the Big Marsh and found the cameras and tripods, which we had cached there last night, had weathered the deluge in their tent made of my bed cover and a tarpaulin. It is some island. Last night I hesitated to carry the cameras in because of the dust and grit that was blowing---this morning the sand is packed hard and all the lowlands flooded.

P. cuneatus seemed to entirely disappear from the island during the blow save for a few scattered groups huddled above ground in sheltered nooks. However, they appeared from nowhere and within half an hour after the sun burst through they were busy excavating the burrows, which have been completely filled and all trace of them lost for nearly a week. In digging they use the bill as a pick to some extent, at least when they are starting a burrow and are above ground where they can be easily observed. In the loose sand of the high ground the pick work is not as important as the shovel excavation. The latter they do by lying first on one side for a time and then on the other and driving the dirt out behind him in rapid jets that fly 2 or 3 feet in the air when they are working rapidly.

The poor Sooty-backed Terns were flooded out from their big colony and have abandoned it to the last tern for a new station where the thousands upon thousands of birds have again gathered in a compact colony. The new site is still in, or on, rather, the carpet of *Sesuvium*, but on a trifle higher ground to the south. Big Marsh is at last a name that fits the place we have been working---or trying to---since before the storm began. The water table was only a foot or so below the surface even when we came, being held there apparently by an underlying stratum of coral or phosphate. Until last night only tiny holes a foot or yard across were all that gave access to the fresh (?) water which, stinking and brackish as it was, was all the birds had. Today, however, the drainage from the deluge has set the whole country afloat. The little water holes are sizeable duck ponds and there is 2 or 3 inches of standing water between them.

Figure 43. The TANAGER Expedition camp on Laysan Island prior to the great sandstorm of April 23-27. Photograph by Donald R. Dickey.

The teal are new ducks! From the dumpy things of the last week weathering out the wind and drought with heads under their ruffled back feathers. Today they are real little ducks, perked up no end, and waddling about from tiny pond to pond with a contented proprietary air. The rain was worth it for their sake alone, for the terns will soon have a new crop of eggs. Luckily laying had just commenced, although there were more eggs than I thought last night in my hasty survey. Today we saw the remnants of 50 or more, but early as we were the curlew had not left one whole egg.

Wandering Tattlers, too, are more common than I have seen them. Perhaps that is simply because I have not worked the beach much. At all events they have swarmed into this fresh water this morning. Turnstones, too, are running about each little fresh lagoon and the healthy new-plumaged plover are also plentiful in the flooded area. One thing I can say for the plover---it has only been the skeletized wan birds marked for death by the salinity of the waters, if that it be, without even strength to begin the spring moult, that I have seen robbing nests. Whether this diet is causative or merely a last resort of their weakened condition I know not, but chances are all in favor of its being merely a chance accompaniment, for certainly the curlew all rob nests---some collected in the act have been disgustingly fat---some thin to the point of sickness. All the turnstones seem fat as butter---all, certainly thousands of them---have the egg habit. The Tattler I have not seen touch an egg, as I remember it, though some acted in an extremely suspicious way, prying about the Hawaiian Tern colony when we were making pictures at the south end of the island. Think I got good film of the teal and shorebirds.

Figure 44. The TANAGER Expedition camp on Laysan Island following the great sandstorm of April 23-27. Photograph by Donald R. Dickey.

Hurried back to the cameras after lunch and packed the Parvo and tripod etc. down to the beach at the SE end of the island. This is site of the main Man-o-war bird rookery, on a low rock escarpment, but they were shy so we quickly turned attention to the "brown gooneys" (*D. nigripes*). Think I got some fine dances unless I wrecked myself by trying to get world beater shots with clouds back and possibly underexposing with "K2" filter on Orthonon stock. Their dances delight me more and more. By contrast they are as a short-necked swan cake walker---the Laysan bird a mere half -hearted gull-like bobber.

Dill or someone has suggested that the reason they nest on the crest of the weather beach is because "possibly the Laysan bird took and held the more favorable lagoon-shore and west ridge-nesting sites." [Although both Dill (in Dill and Bryan, 1912) and Fisher (1906) mention the pattern of distribution of nesting colonies of these birds, I could find no quote similar to this regarding its cause in either publication.] It amuses me to think of what *nigripes* would do to *immutabilis* if competition were really keen. The latter would, I imagine, go by the board in short order. A saner explanation, it strikes me, is that the sturdier bird chose the windward ridge where a clean-cut run allows it to "take off" easily upwind while the weakling took shelter despite the added difficulty in rising from the level inland surfaces.

Now, at last, I had *nigripes* in sufficient quantity to wind up the matter of the white-marked birds. I had seen so little indication of white rump and crissum elsewhere that I came to think them absent from the island, but they were there today in all degrees up to a light brown bird that is the extreme in whiteness of all seen. The size of this extreme individual and one or two others that approached it may indicate an average sex difference in this matter. Those exhibiting the white gave a general impression of extreme and grizzled age, but this maybe a mere chance similarity to men and dogs that grow hoary with

years, since this phase exhibits an increase of the light face ring and general grizzled body tone.

10 Tropicbird and egg under bench---camera pack Man-o-w Bds---poaching---dead carcasses---sailor said 200---now sand covered---Japanese for fish trolls? At 4:00 terrific rain---packed in 75 pounds. Threatening banks and heavy showers in eve. Fine swim. Mullet for supper---net---wont bite

Mortality due to storm---2 gooneys---several Bluefaced Boobs. Most of the Man-o-war bds eggs. All of one col. of S.bk Terns---tobacco patch doing well. Xmas Island shears. (wind). Wedge tails---minor---3 found. Nothing else noted. [Dickey's journal ends here, although he did not depart Laysan until 30 April.].

SPECIES ACCOUNTS FROM THE FIELD NOTES OF ALEXANDER WETMORE

[I have used the currently accepted nomenclature for the species headings, followed by Wetmore's usage in parentheses when this differs. I have left the names of the islands as Wetmore used them. Bear in mind that in French Frigate Shoals, the name King Island was changed to East Island, a correction that Wetmore never made in his species accounts. Also remember that Ocean Island is now Kure Atoll, Gardiner Island is Gardner Pinnacles, and Lisiansky is now spelled Lisianski. Wetmore almost never put more than the bare essentials of data on his specimen labels, reserving other observations for his species field notes. In later years he was always careful to note soft part colors for at least one or two individuals, but unfortunately in 1923 he was lax about this, so that practically nothing was recorded for the endemic land birds, apart from detailed notes on the Laysan Teal. Wetmore himself (1924) had to take the colors of the Nihoa Millerbird from dried skins. The absence of this information is especially unfortunate in the case of the Wake Island Rail, which is now extinct.]

Black-footed Albatross *Diomedea nigripes*

Laysan Island

May 2. Many. May 3. The number of these birds has decreased about one third since I was here last. I am told that during the recent severe sand storm all of the adults left the island, leaving the young to fend for themselves. The young bird in seeking food utters a low drawn out sibilant whistle which is repeated steadily "tsee tsee," given in a slow fashion. At the same time it nibbles at the bill of the parent. The latter, after crouching etc. as described above, when ready to feed opens the bill widely throwing tongue and glottis forward while the young thrusts its bill crosswise through that of the parent and with a rapid scissoring of the mandibles scrapes up the food as it is regurgitated. Sometimes the latter is simply a thin fluid but is carefully taken up by the youngster. The notes of adults are high pitched whistles, uttered excitedly during or before the dance, that sound like the squeak of a rusty pump running rapidly, or at a distance resemble the shrill whistle of a boy. The latter is so close that frequently I have turned to see if some of the men were whistling to attract my attention. Tips of primaries show wear from slicing through waves [or perhaps through sand, as described below for *D. immutabilis*].

May 4. Two females seen had excavated little nest cavities in the sand in one case beside a half gown young bird belonging to the bird in question. They crouched in these forms turning about and working the sand with the bill as though preparing to nest again. Another with no youngster had worked out a similar small hollow when her mate dropped in beside her. For some time the birds caressed one another by working the bill in the feathers of the head of the other, doing this in alternation. They then stalked solemnly about looking down as though peering at an egg. As I sat in the sand watching them, four Laysan Albatross came up curiously behind me. A pair of *nigripes* joined them and finally the pair I was watching came stalking up. In walking the neck is drawn in, the head lowered and the bill pointed forward while the bird walks along with a stiff and awkward waddle.

May 5. The majority of the Black-footed Albatross nest along the north and east beaches. On the eastern side a few overflow down into the Laysan colony and once in a while they occur among groups of Laysan. Some young are located in the edge of the wash from high tide where they are wet twice a day but show no inclination to move. Like the Laysan Albatross the young excavate little depressions in which they crouch and sleep and rest.

May 6. In the past few days I have examined several hundred and in only three or four have I noted light bases on the rump feathers. None show the white rump seen frequently at sea. It is possible that the latter are immature birds and that they do not come to breed until they are two years old. Females are distinctly smaller than males and are often lighter in color.

May 7. Occasional individuals drop in among the Laysan Albatross and take an active interest in the young of that species. Frequently one crouches near a nestling *immutabilis* with a distinctly proprietary air. Though individuals of the two species quarrel somewhat among themselves I have observed no clashes between *immutabilis* and *nigripes*.

May 8. This afternoon I made the entire circuit of the island while making a count of the young albatross. During this I remarked four *nigripes* that showed the white rump patch and white under tail coverts prominently. The first of these, a male, was very wild and flew when I came near. This bird I collected, with the shot at the lower end of the back that seems fatal to these birds. The other three were females, all of them with young. In two of these birds there was evidence of an arrested molt so that apparently a plumage had held over several months longer than usual. The vast majority of albatross here are in full dark plumage with only occasionally an individual that shows a little white at the bases of the upper tail coverts. The dark plumage then must be assumed to be the adult. One old female charged me savagely today with spread wings and snapping bill from a distance of 40 feet, though I was passing quietly along paying no attention to her. I had to fend her off with the gun and she returned several times to the attack. I saw one feeding today, raise a bolus the entire size and shape of the stomach and transfer it in one piece to the young.

May 13. One flew into another an knocked it over on its back and the prostrate bird had difficulty in righting itself again.

Ocean Island

April 17-19. About 300 pairs nesting. Have young well grown though still in down. The birds breed in little colonies on open sandspits or scattered along the beaches.

Dead adults were numerous. April 20-22. Common. The feeding of young of this bird is interesting. The parent stood by the youngster which uttered a little whistling note and nibbled at the adult's bill. The parent closed its eyes and crouched on its breast with bill partly open. Soon it rose to a crouching position and began pumping the tail, apparently regurgitating with great effort. The bill was partly opened and as the food appeared the young one thrust its bill in the parent's throat and secured it. Small morsels were brought up at a time and the last ones were thrown up with great effort that produced a groaning note. The parent kept its eyes closed throughout the process.

Midway Island

April 23. On Eastern Island at least 1000 pairs occupy the outer beaches where they have well grown young. April 24. Fully 1000 pairs on Sand Island. Two taken. April 25. Many over wake of ship at sea.

Figure 45. A Wetmore skinning birds on the beach on Sand Island, Midway Islands. April 24, 1923. [A Black-footed Albatross walks in the foreground.]

Pearl and Hermes Reef

April 26. Abundant on Southeast Island. The birds nest along the sand beach and do not go inland among the grass clumps. Though strung out everywhere, they have a tendency to form colonies where 50 to 100 rest a few feet apart, usually near projecting sandspits. They do not seem to mind exposure to weather. Some young show development of breast feathers. About 1000 pairs. April 27. About 800 pairs on Grass Island. About 1200 pairs on Seal Island.

Lisiansky Island

May 16. Common. May 18. Some young are well fledged, others are merely assuming breast plumage. I saw one standing today with wings spread in the trades in which the wings were almost as long as in the adult. The young are moving about considerably. One young bird had a prolonged sparring match with a young *immutabilis* in which the two clattered their bills and fenced without actually doing one another any harm. One young bid threw the bill up today and uttered a wheezing groan in imitation of that of the adult. These birds are more wary here than on Laysan and are difficult to catch.

May 19. Today a female came flying in to alight near her young to which she hastened with evident affection. The youngster began teasing for food and the female settled herself to satisfy it. A young Laysan Albatross resting inoffensively twenty feet away caught her eye and she ran over to it, shook it by the neck irascibly while the youngster snapped his bill and then in fear bowed his head. The large bird ran at this youngster and another nearby several times until they managed to shuffle far enough away when with backs discretely turned they managed to avoid detection. This morning a bird marked curiously with white was taken on the flats in front of camp. About 1000 pairs here. May 20-27. Albatross hung behind the ship constantly from Lisianski to the shores of Oahu. None seen on land at Gardiner.

Nihoa Island

June 11-16. One or two albatross hung over the wake of our ship as we came west past Kauai to Nihoa. Is this due to the fact that we had a following wind?

On Nihoa there is a colony of 60 pairs on a small flat below the pinnacle point of Millers Peak at a point about 850 feet above the sea. The young are well grown and a number have the wings fully feathered so that they should be on the wing in a short time. The colony occupies a slight basin with stony bottom that is free from bushes. A few of the young had wandered out into the shrubs on either side. 8 or 10 were in full feather and showed no down but the majority had down about the head. On June 14 I saw three adults among them but did not actually see them feeding. The majority of the young sit about as they do when young, but a few were walking in the erect position. All had black rumps and heads with no sign of white. Astonishing to find them so high in the air.

Necker Island

June 17-19. Many young practically grown are found on the higher slopes with the Laysan Albatross. A few have down clinging to the head and neck but many are seemingly adult except for a slight lack in wing development. During our stay here I have seen no adults with these birds and believe that they have been deserted. They seem healthy enough and walk about without difficulty. June 20. About 100 pairs here. No adults seen whatever. June 29. Young somewhat more developed.

French Frigate Shoals

June 22-23. About 75 young on King Island, about 90 young on Round Island a [two?] miles northwest. On King Island a few adults are still feeding young that have not quite attained adult stature, but the majority, now well grown birds with only small patches of down on head and neck, have been left to their own devices. Though some of the smaller ones, perhaps those abandoned too early, whistle plaintively and tease their elder

brothers for food, the larger ones seem undisturbed as they walk about, rest in the sun, or play with sticks and pebbles. At frequent intervals they extend the wings and either hold them stiffly or flap them in the steady breeze. A shower of rain always starts this reaction among them. Some rise on the breeze and sail a few feet. This tendency to sail with the wind is their protection in learning mastery of the air. They approach the edge of the island and finally sail out over the water to drop on its surface after a few feet. The breeze then blows them back to shore where they may essay another attempt. If they went off with the wind they could drift away from land and finally perish. Mortality among young albatross on the high islands must be very heavy. One may wonder, for example, how many of the birds on Millers Peak on Nihoa survive to the adult stage.

June 24. 50 young on Trig Island, 30 young on Skate Island, 90 young on Whale Island.

June 28. 8 young on Tern Island. I have watched these birds carefully during the period of our encampment here but have seen no feeding by adults. The young birds wander about seeming perfectly contented, picking up bits of stick and tossing them about, occasionally, as some strong gust of wind comes running along the sand, with wings extended. Seemingly they regurgitate the collected squid beaks in their stomachs as I find large pellets of these. This afternoon I saw a few adults resting on the water. Comparatively few are seen however compared to the number present over the ship's wake earlier in the season.

Johnston Island

W. G. Anderson states that when he was here in November 1922 he found one with an egg on the beach of Sand Island, but that he has never seen the birds at Christmas, Fanning or Washington Islands, even at sea.

Laysan Albatross *Diomedea immutabilis*

Laysan Island

May 2. These albatross have decreased about one third in number since I was here last [Wetmore evidently made no notes on this species during his first stint ashore on the islands]. Apparently part of those that had lost their young have left the island. Young are growing rapidly and in some cases have assumed the breast feathers of the fall plumage. The young birds, toward nightfall, with awkward strokes of their big feet, excavate little depressions in which they rest and spend the night. These are dug to a depth of 3 or 4 inches and, as at the cabin may be made in the slight lee afforded by a fallen coconut frond or a stone. These may be occupied during the day, or the young may wander about a little. I have seen them waddle out of one nest and move to another 30 feet away and there establish themselves. They have a comical way of teetering in the nest on the back of the tarsus with the big feet waving up and down in the air. They look about alertly and clatter their bills and snap at my hand if too closely approached.

May 3. I am told that during the heavy sand storm all the albatross left the island leaving the young to fend for themselves. In early morning hundreds of the great birds beat back and forth over the outer edge of the reef or beyond it in front of camp, their white breasts gleaming in the morning sun as they turn.

May 4. In swinging over the sand hills these great birds frequently swing on one side so that the tip of the lower wing marks a thin line in the sand exactly as they do over the waves. In early morning the sand is marked by these lines in all directions. One seen crouching over a last year's egg partly buried in the sand acting as though on a nest.

May 5. Along the western side of the lagoon there are a number of young albatross within 30 or 40 feet of the water's edge. The wind, from an easterly direction, whips the heavily alkaline water into a foam on the beach which is blown out across the flat. This strikes the young birds who snap at the larger masses, and keeps them continually wet and bedraggled but does not seem to injure them as a number are so large that they are attaining full plumage. When we sit down in the sand it is usual for a pair or two of these albatross to come solemnly up to inspect us. Any new object at the shacks in camp, a water breaker, a box, or pile of rope, is sure to attract the two who have a young on the sand in front and they come walking up to look it over. This afternoon Schlemmer dug a deep hole to bury some bird bodies, throwing up a pile of sand three feet high. One of the birds came over, made appropriate movements and sounds as though it had just located a nest, and then proceeded to climb to the summit and squat down. In the level area near the lagoon which is liable to be flooded the birds build their nests up to a height of six inches or more. The turrets still remain though most of them have no young. Destruction of eggs along hereby flood water was heavy and the eggs entire or broken may be seen in numbers. Almost all of these albatross nest in this inner basin.

May 7. A female filled with parental love tried hard to hover her baby two thirds grown, and nearly as large in body as its mother, greatly to the disgust of the youngster. The mother walked about the baby trying to step up on its back while the child turned about

Figure 46. C. E. Reno and Laysan Albatross. May 10, 1923.

snapping angrily and throwing her off balance. Finally she backed up against the nestling and, settling down, turned her head with one eye up in a ludicrous attitude of contentment. Last night when out with the flashlight, though sometimes young were accompanied by their parents, often they were sleeping alone. Always the adults rested several feet away when they did accompany their youngsters. Adults seemed dazed by the light of my flashlight and when they looked behind and saw their own moving shadows were greatly frightened by them. Tonight at the well a pair went through many courting antics, with their youngster a few yards away. The female crouched on the sand, now half rising to look beneath her, and now reaching out to pull in bits of sand as though forming a nest. The male who stood or crouched beside imitated all her movements and at frequent intervals the two nibbled bills or scratched each other's heads with their bill tips. One or two others stopped occasionally to look on and, their curiosity satisfied, passed along. The male is decidedly larger and heavier than the female but both are colored alike save that the coloration of the bill in the male is slightly brighter than in the female. It seems highly probable from their actions that they remain mated for life. The birds are trim and handsome with stately yet easy bearing---as beautiful as any birds I have known with their soft yet contrasted colors. They seem highly intelligent too and take a friendly interest in me or in anything else that is new. When one comes stalking up to me it looks me over from head to foot, looks at my gun and seems to take in every detail. Certainly a remarkable bird.

May 8. Apparently the eyesight of these birds at night is very poor as one brought into our bedroom blundered about into everything in the room although illumination was fairly good.

May 9-12. Weights of albatross: male adult, 5 pounds 3 ounces.; female adult, 5 pounds. The dance of this species is certainly peculiar. It is divided into a number of movements that may be repeated in varying order. Ordinarily the dance is between male and female of a mated pair. Others however may join in, so that three or four may dance together. The triangles frequently break up in a fight however. As usually given, male and female approach one another walking quickly and, as they meet with head erect, rise on tiptoe and then sink back and bow quickly several times. They may walk about one another next, with head drawn in and extended up with each step. They then nibble at each other's bills, first on one side and then on the other for three or four times and then raise one wing extending the primaries and holding the shoulder in while they preen the feathers beneath. This is usually done with an audible clatter of the bill. This done the bird may raise the head erect and rattle the lower mandible with great rapidity against the upper, following which with neck erect the bill is pointed straight up while the bird emits a peculiar groan. The action of caressing with the bill is usually accompanied by a high pitched whistled whining. The movement frequently becomes very rapid and when it is hot the birds pant audibly At times they synchronize in movement. At times one does one part of the dance while the other is on another. Often one points the bill up and groans or clatters the bill while the other preens the wings. The bill caress when done rapidly assumes a fencing[?]. The two dance constantly near the young who looks stolidly on merely snapping at either parent if approached too closely. Either male or female may approach the other and, looking down, with open bill, call "Kack Kack Kack Kack," a motion evidently used about the egg. Many are now digging little cavities in which the females crouch as though on an egg. All this though actual mating is several months off and there is no development of the sexual organs. When a third bird attempts to join a dance the others receive it at first but soon become puzzled and turn rapidly from one partner to the other. The mated pair ordinarily try to move away but the male may rush the intruder and knock him over. Last night one received a badly sprained leg in this way so

that it was unable to stand but still limped back and rested on its breast while it attempted to follow part of the dance movement.

Shortly before daybreak the adults fly out to sea and feed, and as the sun rises, begin to return. They may be seen swinging back and forth off shore or resting half a mile out in little companies. At nightfall all return to the island to roost. At this time hundreds who have no young come in and the numbers of adults is greatly increased.

Bones collected from the many on the bottom of the lagoon on May 12 were all *D. immutabilis* (det. 9/27/1968). [This sentence was added later at the top of the page.]

May 13. Young are fledging fast. On my arrival here all were downy with only an occasional individual that showed an occasional incoming contour feather along the sides. The birds grew rapidly in size until in bulk they about equalled the parents. Contour feathers spread from the sides across the upper breast and as they continued down toward the abdomen feathers appeared on the wings and finally on the tail. The incoming contour feathers are continuous with the down, which is plucked off or wears off. Tiny filaments still adhere to the feathers, giving an appearance of faint grayish vermiculations, especially on the sides. Numbers now have white shirt bosoms that form a ridiculous contrast to their fuzzy ragged heads.

Ocean Island

April 17-19. About 50 pairs present nesting on sand beaches at the edges of the bushes, either alone or with the colonies of *D. nigripes*. The opening in the center of the island proves a trap for them, as, attracted by the space, they alight, only to be unable to rise on the wing again. The surface of the ground is uneven and grown with grass and vines. As the birds running awkwardly in this take off they stumble and fall before they can gain sufficient momentum to rise. I found bodies of a dozen in a casual walk where they had starved. Only once did I see one able to get away against the wind. I caught one and tossed it into the air but it fell to the ground like a sack of meal. April 20-22. Common. A pair taken. These birds frequently associate with *nigripes* on the beach. There is a young albatross in front of our tent here that we have speculated about somewhat and a Laysan that dropped in one day to visit seemed to establish its identity. Later however I found *nigripes* feeding this young bird so that the visit apparently was merely a friendly one.

Midway Island

April 23. Abundant on Eastern Island where the birds nest mainly in long openings among the *Scaevola* bushes. It is difficult to judge their numbers but there are certainly more than 1500 pairs, all with well grown young. April 24. Abundant on Sand Island where there are 1000 pairs or more in openings or along the beaches. From their familiarity with man the birds are extremely tame. As I skinned one on the beach, a living bird came up and examined its dead companion curiously. The birds when dancing, sometimes resent interference by a third partner who wishes to participate and I saw several rough and tumble fights in which the birds rushed and bit savagely, tumbling their opponents over and over and returning again and again to the attack. April 25. When seen at sea these birds may swing by but do not follow the wake with the other goonies. At Midway they are said to arrive in October to nest and depart in June.

Pearl and Hermes Reef

April 26. About 300 pairs on Southeast Island. To my great surprise as I stopped to examine something in the grass, an adult with a young one near by ran up and bit me severely in the calf of the leg. This is the first time that one has actually taken the offensive. Numbers of young here have the white breast feathers fully developed and wing feathers starting. April 27. One hundred pairs on Grass Island, 150 pairs on Seal Island. April 28. Though a [few are?] scattered along the beaches [with?] the other goonies the majority nest inland on the higher part of the island.

Lisiansky Island

May 16. Fairly common. May 18. Laysan Albatross here are dancing steadily as they were at Laysan. I have seen one or two loving mothers trying to hover large young who snapped and bit to avoid the attention. As a matter of fact the young never seem to show any regard for their parents except when being fed and the parents themselves usually merely rest near the young and seldom touch them. The nest site choice and the pretense of an egg are seen repeatedly and occupy much of the time of adults. This evening two were dancing with a third nearby who tried to join without success. The third bird finally turned and assumed dance position with a *nigripes* who made one or two half hearted returns of the advances with thrusting bill. The *immutabilis* fenced and bowed slowly for several minutes but as the *nigripes* remained stolid finally gave up in disgust. Young here are just assuming breast plumage and on the whole are slightly less advanced than on Laysan. May 19. Not more than 800 pairs on this island. The birds are as a rule wilder than at Laysan Island. Numbers were seen gathering to rest in close company at sea sometimes in company with *nigripes*. They are dancing steadily here as at Laysan.

Gardiner Island

May 22. On the northwestern slopes of the large rock I found two nearly grown young resting in small depressions on the rock face one hundred feet above the water. They remained quiet, not moving about as they do on low open sand islands.

Nihoa Island

May 24-26. One seen occasionally sailing past the western cliffs. June 14. One reported on Millers Peak with the other albatross. Photographed by Cooke.

Necker Island

June 17-19. Common on the points of the hills. Young are now almost grown and in many cases have lost a great deal of the down on the head and neck. Others have the body covered with fall plumage but the head and neck downy. Their wings are still undeveloped. Though the birds sit about as when younger they walk readily now and often stand with wings extended to catch the breeze. Adults are dancing still but not as steadily or regularly as last month. In one male that I skinned I noticed a few new feathers growing on the abdomen. The plumage of the back is beginning to appear worn. Adults often preen the head of the young, a caress that seems to be greatly enjoyed. The affection of these beautiful birds for their young is remarkable. The young at times regurgitate large pellets of squid beaks.

June 20. 600 pairs estimated on the island. There is considerable mortality among the grown young with no particular cause evident. I have seen about 75 nearly grown birds dead during my stay here.

June 29. Some of the young birds now have wings almost grown. They stand and wave them in the strong wind occasionally rising a few inches and supporting themselves in the air. I found two or three dead or nearly drowned[?] down near the sea where they had fallen in attempting to fly.

French Frigate Shoals

June 22-24. King [=East] Island. About 100 pairs nest here. Young in some cases have lost most of the down and extend their wings in the sweep of the trades, especially during showers of rain. Adults are still attentive to them and feed them and are seen dancing occasionally but do this in a half-hearted way. One adult taken had begun the body molt. June 26. One young on Trig Island, one on Skate Island and 25 on Whale Island.

Johnston Island

July 10-16. One young bird nearly ready to fly, apparently deserted by parents, is the only one on the island. A photograph taken of it. (This photo roll was lost. No print made.) [Note added later.]

Wake Island

August 5. On the lagoon side of the main large island near the channel separating it from Wilkes Island I found three weathered humeri, heads of 3 others, and a tibiotarsus. These have remained packed away until Sept. 27, 1968, when I have identified them as *D. immutabilis*. Specimens turned in to be cataloged. Of definite importance as a record of this species on Wake.

[I have not traced the basis for the relatively recent inclusion of Wake Island as once having been in the breeding range of both *Diomedea immutabilis* and *D. nigripes*. (e.g. King, 1967; Jouanin and Mougin, 1979). On the U. S. Exploring Expedition, Peale (1848:290-291) found albatrosses breeding on Wake on 20 December 1841 and collected an egg that is now in the Smithsonian collections (USNM 949), labelled as *D. immutabilis*. Peale regarded all North Pacific albatrosses to belong to a single species, *Diomedea brachyura* [= *D. albatrus*], the Short-tailed Albatross, under which he listed *D. nigripes* as a synonym (*D. immutabilis* was not named until 1893). In addition to the egg, the identity of which may be no more than a surmise, there is a skin of *D. nigripes* (USNM 15552) labelled as coming from Wake Island and attributed to the Exploring Expedition, that was cataloged as *D. brachyura* in 1859. Its only label is neither original, nor probably contemporaneous with the date it was cataloged, when it was noted as being "unmounted." The specimen obviously had been mounted at one time, however, in addition to which it is in excellent condition, in marked contrast to so many Exploring Expedition specimens. If this really is the same specimen that was cataloged as 15552, then it must have been mounted from an unmounted state, and then dismounted, which would imply that it had been on exhibit. Although opportunity probably existed for mislabelling, a specimen of albatross from Wake surely existed at one point and there is no reason to believe that it is other than the one now on hand. This is the only evidence I know of to substantiate the species *D. nigripes* from Wake.

[The bones (USNM 502088) that Wetmore collected from the poachers' midden on Wake and identified as *D. immutabilis* consist of two nearly complete humeri, one distal and 4 proximal ends of humeri, and one tarsometatarsus. Two of the proximal ends, are very neatly cut at almost exactly the same place, as though by a fine-toothed saw. Because they were not identified until 1968, were not cataloged and installed in the collection until June 1977, and were never published, they are unlikely to be the basis of any statement in the literature that includes Wake Island in the range of *D. immutabilis.*

[The apparent extermination of albatrosses from Wake prior to 1923 is a little difficult to understand unless the populations there had been subject to depredations of feather hunters over many years in succession, for which there is no evidence. Because individuals of *D. immutabilis* do not return to land to breed for the first time until between 5 and 10 years of age, and most *D. nigripes* until after 5 years, there should have been ample breeding stock to repopulate the island even after several years of total extirpation of nesting birds. Although there were albatrosses present when the Japanese poachers were on the island, about 1918, Wetmore found very few of their bones among the masses of bird bones that remained. Perhaps Wake was at the periphery of the area encompassing suitable oceanic conditions for foraging, so that populations were never large.]

Northern Fulmar *Fulmarus glacialis*

French Frigate Shoals

June 24, 1923. Tern Island. A mummy picked up on the beach by Grant. [According to Clapp and Woodward (1968), this is the earliest record for the Hawaiian Islands, although it went unreported until their publication. Like the mummified gulls that Wetmore collected (see *Larus*), this specimen was not cataloged until 1967 and was subsequently prepared as a skeleton.]

Kermadec Petrel *Pterodroma neglecta*
(*Aestrelata* large, dark)

Ocean Island

April 20. Three large dark petrels flew back and forth across one of the openings scaling with set wings. They were wild and it was with difficulty that one was secured. [USNM 300679; this is apparently still the only record of the Kermadec Petrel in the Hawaiian Islands, although it went unreported for nearly half a century (Gould and King, 1967; Clapp and Woodward, 1968). It seems not to have been appreciated that the specimen taken was but one of three seen.]

Bonin Petrel *Pterodroma hypoleuca*
(Bonin Island Petrel *Aestrelata hypoleuca*)

Laysan Island

April 8-13. Seen occasionally in evening. May 4. The colony of these birds seems abandoned. May 6. An adult female with ovaries somewhat developed picked up at night in the *Sesuvium* patch. May 7. A bird dead ten days was picked up near the lagoon. May 8-12. Occasional mummies of this species found. May 13. Large numbers of skulls of these birds wash out of the sand attesting to their former abundance. In half a mile along the beach this afternoon I picked up 25 and passed as many more.

Ocean Island

April 17. A few seen. April 18. This evening at sunset we remarked a few of these birds kiting about over the *Scaevola* bushes and occasionally darting out over the beaches. I killed three after several misses. Their flight is swift and batlike and they have a disconcerting way of slipping sideways and banking first on one wing and then suddenly on the other that is not conducive to accurate marksmanship. After dark Grant and I went out with flashlight and found many circling over the *Scaevola* bushes. They darted about overhead attracted by the lights and I killed four more. The birds were pursuing one another with snarling croaks that remind me of the call of the leopard frog. Though circling in twos and threes, they are not breeding, as their sexual organs are not developed. The sandy opening in the center of the island is honey-combed with their burrowing so that in traversing it I fall in to my knees continually. Could find no birds in the burrows. I heard the snarling calls of those in the air frequently after I had gone to bed. April 19. Petrels circled inland and did not come out to the beaches because of the high wind. April 20. This evening (see journal) I crossed to the central opening and remained until after dark. These petrels appeared at dusk and when it was fully dark the air was filled with their swiftly moving forms and I heard their snarling cries constantly. I shot a number by the aid of a flashlight but later came across their breeding colony and caught a number in my hands. April 21. Large numbers of petrels were out at dusk in the meadow. In flight they raise the wings above the body and then bring them down just to the center. Their appearance and motion on the wing is decidedly batlike.

Midway Island

April 22. One picked up on a lawn at the Cable Station on Sand Island. I examined one young bird still in down resting at the entrance of a burrow below the light house. It kept the eyes tightly closed while being handled. The feet showed the characteristic markings of the adult. April 24. Many circling in stiff breeze outside lagoon this evening.

Pearl and Hermes Reef

April 26. The body of one picked up on Southeast Island. A number seen off the reef from the ship in morning and evening. April 27. On Grass Island one of the sailors with me stepped through a petrel burrow and when he withdrew his foot saw one of these petrels struggling in the sand with only its head exposed. Later, on this same island, we found two downy young at the entrance of burrows, animated gray powder puffs that kept their gray eyes tightly closed and uttered low murmurs when handled. April 28. Several seen over the reef in early morning.

Lisiansky Island

May 15. One seen at dusk. May 16. A mummy found and the skull collected. May 17. An expedition to the grass plot with flashlights tonight yielded five of these birds and I saw several more. Unlike the shearwaters they seem to require vegetation amid which to burrow. Those collected were sexually inactive. They contain quantities of oil which is difficult to keep from oozing out on the feathers but which is somewhat volatile as when cleaned off carefully with absorbent cotton it sometimes almost disappears. It is orange in color. Perhaps 50 birds now on island. May 20-21. Noted occasionally at sea between Lisiansky and Gardiner. May 23-24. Seen occasionally at sea between Gardiner and Nihoa.

Bulwer's Petrel *Bulweria bulwerii*

Laysan Island

April 29--May 14. On my return here, the evening of April 28, I found this little petrel common though it was not seen from the 8th to the 13th. The birds appeared at dusk fluttering low over the sand and alighting near the buildings to investigate nooks beneath that might serve for nest holes. At frequent intervals they uttered a muffled barking call that resembled exactly the barking of a little dog. As they passed me on the wing I caught the strong musky odor characteristic of petrels. They are gentle little creatures that do not attempt to bite when handled but rest trustingly in the hand seldom even struggling to escape. When placed again on the ground they often rest quietly, not at all alarmed by their unusual experience. One evening one was brought in to the light three times in ten minutes to settle some point under discussion but when returned to the ground began its calling again undisturbed. On the ground they rest prostrate on the breast and move by shuffling along, barely rising above the earth. When they have any distance to move they prefer to rise in flight. They are found in pairs often but no other mating demonstration than their call was noted.

Many were found after May 1 during the day in crevices in the rock ledges where they were found always in pairs, the two nestling close together. Such pairs were found under flat rocks, or in little cracks often little protected from light. When pulled out they shuffled back to cover. At night when the birds were active they sometimes came to investigate my coat sleeves or trousers legs as I sat on the ground. They were active at dark and swept with light graceful flight back and forth past their chosen ground. They were so small and weak that they gave way instantly when approached by the large aggressive shearwaters who were their neighbors. In climbing about, the bill was hooked over stems to assist in pulling the bird up.

Lisiansky Island

May 16 to 19. Fairly common at dusk. One captured on the wing by means of a hand net was not at all alarmed.

Nihoa Island

May 24 to 26. Seen from ship. June 11 to 16. Abundant. These birds now have eggs. Incubating females may be found in any rock ledge by raising flat stones or peering into the crevices. Males as well as females incubate. One egg is laid. Two were seen attempting to cover shearwater eggs. Most nested under cover but a few were found whole exposed. June 30. Seen at sea off Nihoa.

Necker Island

June 17 to 20. Common nesting as at Nihoa. The barking calls of these birds, muffled and amplified by the rock caves surrounding our camp, had a supernatural sound at night inducing the statement by a visitor ashore for the night that he heard the spirit dogs of the ancient Hawaiians. June 29. Abundant.

French Frigate Shoals

June 25. Tern Island. One taken with an egg under a flat board. June 27. Common on La Perouse Rock.

Johnston Island

July 10-19. Common, nesting in the rock ledges along the beach where I hear their barking calls day and night. They are more advanced in their breeding here than farther north as they have young from a week old to those growing contour feathers. The small young are, as usual in petrels, very fluffy with heavy down about the head that almost hides the eyes. Young beginning to molt into first plumage appear much larger than the adult and in reality are heavier because of the heavy layer of greasy fat that covers the entire body. They remain hidden in the ledges during the day but at night come out to the open shuffling about on the breast. At day they seek shelter when exposed to light. The larger ones resent handling and attempt to bite, as do adults when handled at this season. The young utter a slow whistling wheeze somewhat similar to the note of a squab. Adults delight to rest a few inches apart and with extended head and swelling throat utter their comical little barking call, a note common to both sexes. When quiet they rest prostrate on the breast and in moving merely shuffle along barely raising the body free of the sand and dropping back at once. About 400 on Johnston Island.

Wedge-tailed Shearwater *Puffinus pacificus*
(*Puffinus cuneatus*)

Laysan Island

May 2. During the sand storms that came during my absence many of these shearwaters left the island but now the majority have returned. The thousands of burrows that they had excavated were covered and buried by the sand but they are now busy in excavating others. It is these buried burrows that one falls into constantly in crossing the sandy slope.

May 3. This evening the shearwaters came in great force and were very noisy all night. In early morning before the wind starts the sand everywhere is absolutely covered with their tracks. Seen copulating today.

May 4. My first impression of these birds was that they were exceedingly stupid but as I was watching them the impression grows that their seeming stupidity is merely fearlessness. Tonight hundreds were circling over the ocean outside the reef and many new birds came ashore so that they fairly swarmed over the open.

Today I saw one starting a new burrow. It pecked hurriedly away with its bill and scraped alternately with both feet until in a minute or so it had made a depression 6 inches across and an inch deep. The bill is used extensively in digging. Once I saw one drive the bill firmly in the sand and thus steadied dig rapidly with both feet in alternation so that a steady stream of sand came out behind. Ordinarily one foot alone is used so that the sand comes out in little jets for a few seconds and then stops. The appearance this makes in spurting out of a deep hole is always provocative of amusement. It is observed most frequently in morning and evening.

As I come to know them better I find them aggressive and truculent with dispositions as savage and uncertain as that of a mink. Males fight savagely, pecking with their bills and springing from the ground to strike at one another with both feet. Finally they secure one another by the bill and with flapping wings roll and tumble about now one, now the other on top, scratching with their sharp claws. Meanwhile they utter catlike squalls that, coming from he door or beneath a cot at night, do not lead to pleasant slumber. Tonight a big bully of a male came in and after a prolonged battle whipped a male who had a mate and was excavating a burrow in a sand bank just outside the door. During the battle the female scuttled in and out trying to get near her lord. The victor claimed both burrow and lady and began to call at once in a loud tone. The beaten bird returned to the attack with loud squalls to be worsted each time until finally in the interest of peaceful slumber I collected the victor.

May 5. These birds have come in in large numbers and though common about the shacks are found in still greater numbers near the lagoon. In some places there the ground is almost black with them. They are busy mating now and are usually in pairs, though many do not seem to be in breeding condition. Twice in the last two days it has been reported that a male *cuneatus* was trying to copulate with a female *nativitatis* and this evening I witnessed this myself. The *cuneatus* was mounted and was working busily but the bird beneath remained meekly passive with tail flattened on the ground. The Wedge-tailed remained mounted for two or three minutes. His own mate rested on the ground a foot away.

May 6. Great numbers of these birds congregate in evening in the vicinity of the lagoon. Areas two hundred feet or more across are covered with the birds resting almost against one another and the number revealed by the rays of the flashlight is enormous. In walking, care was required to avoid stepping on them and the birds blundered into me at every step. Several times this evening I saw males make advances toward *nativitatis* of both sexes. Males beat a hasty retreat but females remained passive though the Wedge-tail was not able to effect actual connection.

May 7. These petrels are found in large numbers about the shacks where they rest about on the sand during the day or occasionally give a low call from some hole beneath the floor. With the approach of dusk they become more active and come sidling in to their burrows from all directions. Many seem to fly in from the sea and alight and then walk or half walk and half fly to their ultimate destinations. We derive much amusement from their maneuvers.

Last night one big ruffian came sidling in to a burrow partly dug by a weaker male and his mate. The two males engaged in battle at once with yowls and screams and carried on a prolonged rough and tumble for several minutes until the weaker one was vanquished and the usurper, seizing wife and home began an amorous song of victory. The second bird returned to the attack several times and the commotion was such that in the interest of peaceful slumber he was finally collected. This afternoon one came waddling quietly up to his burrow just outside to discover an interloper with his wife. With a whoop of anger the irate householder fell on the intruder, gave him a severe trouncing, literally flung him out and then settled for a quiet rest. At dusk another male attempted to wrest his burrow from him and a noisy battle began that lasted for ten minutes. The two rolled and tumbled about regardless of wing and tail feathers binding against the sand. Usually they held one another firmly by the bill while they doubled up and scratched heads and shoulders with their sharp nails. Occasionally one grasped the other by the throat and shook and tore viciously. When they pulled loose they closed again instantly. After ten minutes one had

enough and struggled to get away while the other bit savagely at his head, back and rump. When he finally got out he was a sorry looking object, with feathers rumpled and blood oozing from punctures on the head and shoulders. This bird I collected and found to be a male. The victor began immediately his song from the hole under the barrel that had been the bone of contention. They are naturally combative in spite of their dove-like appearance and delight in a fight. We had some amusement from catching other males and thrusting them in upon the doughty warrior under the barrel. Battle followed instantly, with Dempsey, as we named him, always the victor.

As the legs in these birds are set far back they walk with apparent difficulty, with body nearly horizontal and head on a level with the shoulders while they take short, waddling steps rapidly. After traveling a few feet they plunk prostrate on the breast and remain looking quietly about. Though their walking reminds one of the scuttling of a turtle, when in the wind they rise and skim along, frequently pattering on the sand as gracefully as can be. It is common for them to rest asleep with the head turned on the back. If touched suddenly they spring twelve or fifteen inches in the air as though galvanized, an action common to them at other times when startled. They fall back at one and after a running start with extended wings take flight.

These quietly colored dove-like birds have the vicious dispositions of minks. Even their love making often ends in a brawl. Females will bill with the male who may return the caress and then suddenly strike cruelly and viciously. Males have sexual organs well developed but females are not yet near laying. They feed offshore in large numbers and are much subject to attack by frigatebirds who harry them and often seize them by the wing and whirl them over.

May 8. It seems probable that the family tie in these birds may be very loose. As dusk came in this evening, birds began to gather about the cabin and to shift about from place to place. Some seem to have definite holes, which they protect from all comers. Other openings, partly completed, may be occupied for a few minutes by one bird and then left to be taken over by another, until several may have claimed a temporary possession in the course of half an hour. When a male approaches a hole it sidles off a little bit and eyes the opening vigilantly until it appears that there is no one at home, when it may take a chance and sidle down. Often three or four may gather about an occupied burrow, undecided as to whether to fight or not. Suddenly one will spring at another and spur him with his feet and the whole collection will spring into the air with spread wings and catlike yowls. After a clinch or two they separate and hustle away. When a male sidles over to some newly arrived female and begins his usual sonorous song, three or four others may hustle over and join in, when they all face one another watching alertly. Suddenly one will move and then all spring into the air with loud screams to drop back and sidle off. I have seen males make approaches to four or five females in succession and it may be that they do not mate permanently. After doing this he began making overtures to a female *nativitatis*, when another male forsook his mate nearby, drove him away, and began himself paying court to the stranger. I saw one tonight mounted on a female *nativitatis* with her own mate crouched a foot away. Unmindful of him the male *cuneatus* crowed his copulation note and worked his tail back and forth across the rump of the bird beneath but with no response as his black skinned inamorata rested passive with eyes closed and tail flat on the ground. When released finally she began immediately to bill with her mate.

May 9-12. The ordinary call of this species is "coo-oo-oo aw-w," the first note made with expiration and the second with inspiration of the breath. Though they still fight steadily there is more of a tendency for them to divide off in pairs. Near the lagoon the

ground is black with them at nightfall. I have taken one that is wholly gray underneath and has light colored feet. It was found with normal colored birds about a hole. It is amusing to see them waddle up to a hole, crouch a few inches away, and then extend the neck to look down over the opening, peering warily to guard against sudden attack by a possible inmate. Their gentle appearance is wholly belied by their character as it is almost impossible to pick one up without being either scratched or bitten.

Ocean Island

April 17-22. During the first two days of our stay Grant reported one or two shearwaters seen at intervals but the birds were far from common. April 20. I saw fifty or more at night in the opening and secured four. April 21. Fully three hundred were circling among the burrows at dusk. My impression is that they had just come to their breeding grounds, as a few had begun calling and digging out burrows as they did at Laysan. Those taken were approaching breeding condition. April 22. A few were seen at sea between Ocean and Midway. In flight this species, in flapping moves the wings for an equal distance above and below the median line of the body. They give a number of strong beats of the wings and then sail with wings set. Their movement when over the meadow suggested that of a flock of nighthawks [*Chordeiles*].

Midway Island

April 23. Common on Eastern Island. April 24. Fairly common on Sand Island. April 25. Fairly common at sea.

Pearl and Hermes Reef

April 26. Fairly common on Southeast Island. April 27. Noted on Grass and Seal Islands. April 28. Several eggs from last year's breeding found in old holes.

Lisiansky Island

May 16. As at Laysan this is the most abundant species on the island. The birds are scattered in pairs or small groups everywhere and I had difficulty in locating a good camp site free from their burrows. I was pleased today to kill another dark gray one and was astonished to secure three more in rapid succession. The first of these birds was walking about peering down holes and the others were flushed at random in the flats. There seems to be more variation from light to dark among these birds here than at Laysan.

May 18. Many of these birds are in sight during the day, resting prone on their breasts, usually in pairs. At dusk there is much movement among them as some go to sea to feed and others come sailing in and quarter gracefully back and forth over the flats, rising and falling lightly, alternating flapping and soaring before settling for a roisterous, boisterous night of hole digging, fighting, howling and copulation. They remind me strongly of lumberjacks or cowpunchers come in for a night in town. Fights are of frequent occurrence and the two combatants seize one another fiercely, the weaker, unconvinced of his inferiority, frequently returning again and again for more punishment. The amount of sand moved during a night by one is at times prodigious and I have seen birds dig until almost exhausted.

In copulation the male gets his large feet planted firmly on the humerus of the female and does not seize her head but swings his bill quickly back and forth across hers.

The flat where we have pitched camp is about the only spot on the island free from their holes. Gray-breasted birds seem to run from 3 to 5 percent of those of ordinary type. I see many that appear whiter below than the average also, so that variation is considerable. There is apparent regular intergradation from light to dark.

May 19. Abundant. Copulation is frequent among these birds but as yet I have found no eggs. I have seen them here attempting often to cohabit with female *nativitatis*. At a conservative estimate there are 25,000 of these birds on Lisiansky.

May 21. Common at sea between Maro and Dowsett and Gardiner Island.

Gardiner Island

May 22. On the western face of the island below the summit I secured one in the farthest recess of a deep crevice in beneath a rock fifteen feet from the outer surface. Dr. Ball reported two others. May 23-24. Common at sea between Gardiner and Nihoa.

Nihoa Island

May 24-26. Thousands of shearwaters circled past the ship. As we lay at anchor many rose high to circle in over the highest peak at an altitude of over 900 feet. Frigatebirds lay in wait for them as they circled to rise in the lee of the island and with lazy beats of their long wings drove the smaller birds downward. If the shearwater failed to disgorge, the pirate often seized them by wing or tail, suspended them, and gave them a shake or two that often started a shower of food. Beyond the lee of the island, hundreds swept back and forth in a twenty-five mile wind, rising and falling over the huge swells apparently purely for the pleasure of it, as none were seen to feed. They rose and fell catching a new equilibrium adroitly with each new gust, or if the wind force failed behind the crest of some huge wave dropping to patter along for a few feet on the water.

May 27. Today I was surprised to see several as we were passing Kaena Point and the cliffs at Waianae on Oahu 10 to 12 miles offshore.

[Back at Nihoa] June 11-16. The most abundant species in the island, estimated at 30,000 individuals. The birds are now laying and fresh eggs are scattered everywhere over the slopes of the island. The soil of Nihoa is thin, overlying solid rock and is filled with stones so that it does not lend itself readily to excavation. In a few places on the slopes where earth has collected the shearwaters have dug their usual burrows sometimes three or four feet long but ordinarily merely in far enough to furnish shelter. Elsewhere the birds have sought little natural cavities in the rock, or have gone in under overhanging ledges. Many, fully half in fact, have simply laid their eggs at random in little hollows or depressions beneath the bushes. The eggs are large and white in color and in general appearance are closely similar to those of the domestic fowl. In fact, had someone brought me one casually I should have suspected them of a joke. As I walk through the bushes I see them by the hundred and always am struck by their beautifully clear white color.

The shearwaters themselves are more quiet now than earlier in the season. Occasionally groups are still mating and fight and squall as elsewhere and newcomers are prospecting for nest sites. It is not unusual to wake up in the night to find one resting on my legs as I lie in bed under the overhanging rock that serves us for shelter, and new members of the party who have not had our previous experience complain somewhat of their noise, but to the rest of us they seem very quiet. In passing over the island I see them

resting quietly on the ground, usually on an egg but often merely resting in the shade. When incubating they often exhibit a tendency toward secretiveness and crouch with head extended and eyes partly closed. One held this position for nearly an entire day a few feet from where I sat skinning birds. This same individual seemed to have a poor sense of location. During the second night of our stay another shearwater laid a few feet from the one under discussion, who, when she came in from the sea, seemed undecided as to which egg to claim and waddled from one to the other several times, finally locating on the wrong one. As I pass through the brush they sometimes leave their egg and hustle awkwardly away with wings and head catching in the brush. Others rise and offer fight. When one passes too near another incubating bird, the latter immediately voices his indignation in no low voice and seizes the intruder by the nearest part of his person. The eggs cooked are very good eating. Wastage in their eggs is tremendous. Some females apparently lay at random and, it would seem, do not return to such eggs. Finches destroy quantities of eggs left thus unprotected and I see hundreds of broken eggs. Males share in incubation. Of three taken from eggs one has been a male. I see occasional individuals here with gray breasts though the great majority are white. Many circle overhead during the entire day but are most active morning and evening, when the air is filled with them. Parties often rest on the water and occasionally a raft containing several thousand individuals may gather.

Necker Island

June 17-19. Common but in less abundance than on Nihoa. The birds have eggs scattered about over the slopes, most of them showing slight traces of incubation. I saw one instance where two eggs had rolled together and one bird was incubating both. June 20. About 3000 pairs here. The calls of these birds echo along the rock cliffs at nightfall with a weird cadence that is ghostly in the extreme and with the barking notes of the Bulwer's Petrels may have given rise to the belief that the place is haunted. June 29. No change.

French Frigate Shoals

June 22-23. About 50 pairs on Round Island. About 1750 pairs preparing to breed on King Island. Many of the birds have eggs now on King Island and at dusk great numbers of others come in from the sea until they rest in little groups over the entire land surface. Mating is still taking place and their moaning makes music all through the night. Wastage among their eggs is considerable as many are laid at random. I was amused in watching one female with what was evidently her first egg. She had laid it and knew that she was supposed to do something with it. She rolled it about on the sand with her bill and pulled it under her breast. This was uncomfortable, so she worked forward,finally falling off and leaving the egg uncovered. This process was repeated half a dozen times until she rested, tired out, a few feet away. June 24. 20 pairs noted on Little Gin Island. June 26. 50 pairs on Trig Island, 30 pairs on Skate Island. 500 pairs on Whale Island, all with eggs. June 27. 50 pairs on La Perouse rock. June 28. 250 pairs on Tern Island. Many eggs scattered about in burrows or on the ground.

Kaula Island

July 1. Abundant over sea and circling over high slopes.

Johnston Island

July 10-18. One of the abundant birds of the island now well along in the breeding season. They are still calling at night to a limited extent and I find occasional fresh eggs, but the majority are now incubating. I have looked carefully for young but have found none. Apparently this species has a uniform laying season, as condition here corresponds to that on other islands visited. Now that incubation has begun, *cuneatus* has changed completely in character. It is a close sitter and crouches on its egg motionless, making no sound at all for hours on end. Apparently one adult incubates by day and the other by night. Young terns that chance to fall in on the shearwaters are bitten and driven away, as are other shearwaters, and occasionally one starts its war cry when a random footstep starts a rain of sand on the occupant of some burrow. Ordinarily they scuttle awkwardly away with bill and wings catching on the vegetation without making a sound. Some eggs are laid in the depths of burrows four feet from the entrance, others under little mats of vegetation above ground. The entire island has been dug over by the birds and one falls into their holes every few steps. The openings of burrows are usually a foot or more across as the loose sand falls in at a touch, enlarging any hole that is made. By day the only ones visible are the few whose nest sites leave the incubating bird visible wholly or in part. At dusk scores come sailing in from the open sea and after dusk the flashlight reveals them on the ground in all directions. In evening rapacious frigatebirds cause many to disgorge, a disagreeable task that the shearwater postpones to the last possible moment. I have seen many a one driven down repeatedly by its broad-winged pursuer until it struck the water. Then it dodges about and attempts to fly but makes no attempt to dive. I see a fair number in the gray-breasted phase and secured one mated pair, both dark in color. The white-breasted individuals are greatly in the majority. At dusk the paired birds often rest facing one another and caress head with a nibbling motion of the tip of the bill. About 2500 on Johnston Island, about 500 on Sand Island.

Wake Island

July 30. A colony of perhaps 50 pairs found in loose soil in openings among the trees on Peale Island. Males apparently settle down after sowing a few wild oats during mating, as I found several males incubating among those taken today. Eggs appeared hard set but I found no young. August 2. A few burrows on the northern portion of Wake Island.

Sooty Shearwater *Puffinus griseus* (*Puffinus gravis* [sic])

Laysan Island

May 3. One washed up on the beach too far gone to skin. Very thin, dead for about ten days. Head, wings and feet preserved. [Wetmore's use of *Puffinus gravis* appears simply to be a *lapsus calami* for *P. griseus*, the Sooty Shearwater, rather than a misidentification, because the species *P. gravis* does not occur in the Pacific at all. The specimen (USNM 289182) is now preserved as a partial skeleton. Curiously, the original label, in Wetmore's hand, identifies it as *Puffinus cuneatus*, under which name it was cataloged and installed in the collection. At some point I reidentified it as *P. griseus*, but this must have been after 1973, as the record is not mentioned by Clapp and Woodward (1968) or by Ely and Clapp (1973:120), who reported another specimen of this species taken at Laysan in 1906. The Sooty Shearwater migrates regularly through Hawaiian waters.]

Christmas Shearwater *Puffinus nativitatis*
(Christmas Island Shearwater)

Laysan Island

April 8-14. Fairly common. Found in pairs and a number collected. One fresh egg found under a board and another taken from the oviduct of the female. April 30-May 4. Common. Another egg taken from oviduct of female. This morning I witnessed a rough and tumble when one male attempted to take possession of the burrow of another that lasted five minutes. The two seized one another by the bill and scratched and rolled with beating wings in and out of the burrow. The owner finally victorious crouched on the sand where he could guard his home and uttered his cooing call loudly mindful of the fact that his eyes were full of sand and his plumage ruffled. The other, twenty feet away, also began to call,and I tried to drive him back for another battle but he flew precipitately.

May 5. Common. May 7. These shearwaters are common and are much more likeable birds than the vicious *cuneatus*. In spite of their heavy bodies they spring into the air and fly without difficulty, especially if there is a little breeze. A female today was found covering an egg in a hole in a pile of rock. The pure white egg was deposited in a little hollow on the sand with no nest material. The birds begin activities toward dusk and move about constantly after dark. In morning they remain out for two or three hours to enjoy the warm rays of the sun. In walking, the body is held horizontally with head on a level with the shoulders. Progression is effected in a rapid but somewhat awkward waddle and after a few feet the bird drops heavily on the breast. If they have far to go they prefer to fly.

May 8. A number about. May 9-12. The call of this bird is "Kah-h Koo-oo-oo Koo Koo Keh" inflected and varied according to circumstances. As the male gives it he extends his neck and raises his head. When the female is beside him she responds immediately with the first part of the call and caresses the head of her mate who may return the caress or may bite her savagely. Their love making seems wholly confined to a rude and rather rough preening of the head and a touching of bills. In evening and in the morning before day they are alert and active. As the sun rises in the morning they frequently drop down into the shade of rocks. As it rises higher, they may rest and sleep for a time but as its rays become stronger, disappear into crevices of rock or other shelter and are seldom seen during the day. They rise easily in flight from a resting position and on the wing resemble pigeons. The wing stroke is quick and rapid and the wing is flapped with short quick strokes in which the wing tip is not brought below the center of the body. In walking they rise and waddle with body horizontal---as they stop they drop heavily on the breast.

Pearl and Hermes Reef

April 26. Mr. Caum saw one amid the grass but I was unable to locate it.

Lisiansky Island

May 16. Fairly common. An egg found under a board in a hole merely broad and deep enough to conceal the bird. May 17. A female taken with an egg. May 18. Seen. May 19. One fresh egg taken. About 300 pairs on this island. Much less in evidence than at Laysan.

Gardiners Island

May 22. One or two seen circling about ship but none seen on shore.

Nihoa Island

June 11-16. About 20 pairs are breeding on the higher slopes on Millers Peak between 800 and 900 feet elevation. The birds nest in little shelters beneath overhanging stones or tussocks of grass where they may or may not be entirely covered. Both male and female may be found in the nest. Some have eggs, others nothing. I found one nest containing a young bird in gray down about a week old which I collected. It regurgitated a quantity of oily fluid bright orange in color when killed.

French Frigate Shoals

June 22-23. King Island. Two pairs seen.

Johnston Island

July 10-19. There are two small colonies on the island where these birds congregate amid the Wedge-tailed Shearwaters and have nests in holes dug to a shallow depth in the sandy soil. During the day all are hidden underground but at dusk they creep out and remain active all night. Adults are calling and caressing one another though all have large young molting into first plumage. These squirm and bite when handled and utter a curious call, "coo" (given with expiration of breath) "oo-oo" (made as breath is inhaled). The call is like that of adult *P. cuneatus*. At dark the young creep out of their holes and remain in the open but seek shelter either in heavy grass or underground when the sun at high. There is one colony on Sand Island. Adults show some wear in plumage. The note of adults is a curious crowing call "coo-coo-oo-oo Koo Koo Kaw," the first part drawn out and the last given rapidly. They are especially vociferous at daybreak in the morning and for an hour after. About 300 on Johnston Island, about 100 on Sand Island.

Wake Island

July 30. A pair taken on Peale Island in an open growth of *Tournefortia* near the center of the island.

Sooty Storm-petrel *Oceanodroma tristrami*

[This species breeds on many of the islands visited by the TANAGER, but in winter, so that most birds would have departed prior to the expedition's arrival. Wetmore appears to have neglected to write an account of this species, probably because the very few specimens obtained were initially confused with *Bulweria*. There are but four specimens from the expedition, one adult and three chicks with patches of down remaining and tails about half grown. All are from Pearl and Hermes Reef---two from Seal Island, one from Southeast, and one taken by Reno with no indication of a particular islet. In one of Wetmore's tabulations he lists the species from Southeast Island but not Seal, where, however, he listed "a few yg" of *Bulweria bulwerii*, a species that he does not otherwise mention from Pearl and Hermes and that was not discovered there until the 1960's, as the population is very small (Amerson et al., 1974). In Table 5 I have listed this record under *O. tristrami* and have deleted *Bulweria*.]

White-tailed Tropicbird *Phaethon lepturus*
(*Phaëton lepturus*)

Long. 174° W., Lat. 17° 10' N.

July 21. One circled over the ship several times.

Wake Island

August 2. One flew over the island high in air and passed on north. Decidedly smaller and lighter in appearance than the Red-tailed bird which was in the air at the same time.

Red-tailed Tropicbird *Phaethon rubricauda*
(*Phaëton rubricaudus*)

Laysan Island

April 8-12. Fairly common. The birds are frequently seen flying high in air overhead or are found seeking nesting sites in the sand about old rock piles or inside the buildings. Females (presumably) rest with ruffle of feathers and heads drawn in on some site selected as a nest, hugging the sand closely so that I thought at first they were covering eggs. Approach of a mate or an intruder of their own species is greeted by a series of harsh grunting squawks that may be pleasing in some ears but are certainly disagreeable to an extreme in mine. This is forgotten though at sight of the beautiful things that do not seem to resent stroking or petting.

May 2. A number have come in since I left on April 14 are now seeking some shelter beneath which to rest. May 3. Several seen along the beach where they hover over likely looking ledges prospecting for suitable nesting holes. Three that I took all proved to be males. They are hard put here to find any shelter for nests and I doubt if many succeed in breeding successfully here. A few find secluded spots about the buildings or under rocks where they are safe. They sit so close by that it is necessary to push them aside to examine the egg. One near the bird room has an egg with longer end narrowly pointed. One egg laid after nightfall found in the open near the cabin. These birds are extremely awkward in progression on the ground. They bring both feet forward, raise the body and then sprawl forward on the breast with a thud and so move slowly and laboriously forward. Bill in male a dull red becoming orange on rami of mandible; a sooty black line extended back from the nostril to the line of the feathers; iris deep brown; tarsus and basal joints of toes with web between olive gray; outer side of inner toe light nearly to tip, outer side of outer toe light to end of second joint. In flight the feet are extended back so that the black on the end of the toes forms a black patch on either side of the tail continuous of the black tips of the posterior flank feathers. The upper mandible opens widely when the mouth opening is completely closed posteriorly, the lateral margins of the choanae are closely appressed and the fleshy tip of the tongue slips in behind the fleshy knob in front of the choanae, completely closing opening of nostrils.

May 4. One that I captured regurgitated part of a squid. The majority of those seen have one median rectrix developed, the other still in sheath. May 5. The upper end of the tarsus in these birds is frequently worn and abraded from friction with sand and stone. May 7. The eggs of these vary considerably in size and form as shown by sets collected.

Males hover in the air uttering their harsh, explosive barking calls and are answered frequently by females concealed on the nest.

Ocean Island

April 17-19. A number seen. One fresh egg taken from sand beneath a *Scaevola* bush. April 20-22. The tropicbird is more abundant here than casual inspection would indicate as the birds are now nesting and spend much of their time beneath the *Scaevola* bushes. I suppose there are 100 pairs here though rarely are more than six or eight individuals in sight at any one time. They fly about with rapidly beating wings uttering harsh explosive squawks that also greet me whenever I disturb one on the ground. Occasionally one will display in the air by hovering in one spot while it lowers and spreads the tail, at the same time calling vociferously. When tired of flying they swing down past their nest sites for a time or two, hover tern-like for a few seconds and then drop into the dense growth. As I pass through the bushes they protest a near approach by harsh calls or may become vociferous at a gunshot fired a few yards away. After painfully forcing a noisy passage through the brush I came upon them resting on the ground beneath the densest growth where I must break away the branches to get at them. They rest with wings spread slightly and, unlike other birds do not eye me closely but seem rather indifferent though they squall loudly as I put my hand near and bite savagely. Eggs vary from fresh to hard set. Grant and Caum report downy young. The long tail feathers of this are in demand in Honolulu and many of the handsome birds have lost their ornamental plumes at the hand of the men. In fact I have been guilty of plucking a pair or two myself.

Midway Island

April 23. A dozen recorded on Eastern Island. One taken. April 24. A few at Sand Island. April 25. A dozen or more seen flying about between Midway and Pearl and Hermes Reef.

Pearl and Hermes Reef

April 26. About ten pairs found on Southeast Island. April 27. Two pairs recorded on Grass Island, 15 pairs on Seal Island nesting amid high clumps of grass. April 28. Seen.

Lisiansky Island

May 17. Two passed over camp, were attracted back by the flutter of a handkerchief, and one killed. None are nesting here.

Gardiner Island

May 22. About 15 pairs nest here in crevices and little caverns below the summit. One or two had eggs, others young four days to a week old. As usual, the adults sat closely protesting our approach with harsh squawks.

Nihoa Island

May 24-26. Seen. June 11-16. Common over the entire island. At least 400 pairs nest here. One immature on the wing taken.

Necker Island

June 17-19. Abundant eggs and recently hatched young seen. June 20. About 500 pairs. Some have fresh eggs now. The birds seek small cavities for nesting or several may range along beneath a long overhanging ledge 8 to 20 feet apart. Occasionally both parents are found at the nest. Awkward and clumsy on the ground. June 29. Many now are shedding and renewing their rectrices.

French Frigate Shoals

June 22-23. King Island. Four pairs about. One young bird not quite able to fly found in shelter of low *Chenopodium*. Bill black. June 26. One pair on Skate Island. June 27. Six pairs seen on La Perouse Rock. June 28. One pair on Tern Island.

Kaula Island

July 1. A number seen.

Johnston Island

July 10. A few pairs were found about the rock ledges of the shoreline. An egg ready to lay was taken from a female that I collected. Also secured one young bird not quite able to fly. Its notes resembled those of the adult. 8 on Johnston Island, 4 on Sand Island, a frigate seen in pursuit of one.

Wake Island

July 27 to August 4. About 30 seen on the island. One taken July 29 was incubating a fresh egg. Others are seen flying in pairs and circling while they utter their harsh explosive notes.

Great Frigatebird *Fregata minor*

Laysan Island

April 8-12. These graceful long-winged pirates are more or less nocturnal as their dim shapes hover or wheel overhead occasionally long after sundown. Fronds of the coconuts furnish resting places while they perch also upon the buildings. They are tame and unsuspecting so that I caught one at camp as it was engaged in preening its feathers in the morning sun. They are now establishing their breeding colonies, choosing sites where scant vegetation remains, or failing these, slightly elevated ridges. The nest site apparently is chosen by the male. As trees are lacking, he crouches on the ground resting quietly until overcome by his amatory feelings he inflates his gular sac, now a brilliant red, and spreads his broad wings on either side. His head is tilted back and he keeps a sharp lookout overhead with beady eyes. Should a female pass he immediately throws his head farther back to display the balloon, shakes his long wings tremulously and utters a liquid trilling call that is very pleasing. I saw nearly one hundred males resting on one rock pile with balloons distended while hundreds more were distributed along a ridge behind them---truly a beautiful sight. They do not seem pugnacious as they rest in close proximity. Two were caught by hand on the nest.

May 2. Many eggs have been destroyed by storms since I was here last. Males that have enticed a female to the nest extend the balloons fully and swing them from side to side rubbing them against the breast of the female who rested opposite, apparently inattentive. With mating over the male takes on part of the duty of incubation. The pouch

Figure 47. Eric Schlemmer with two adult male frigatebirds with throat sacs fully distended. Bird at right is mating. The one at left has beun incubation and sac is shrinking in size. Laysan Island. May 2, 1923. [Another photograph of these birds was used to illustrate a note that arose in correspondence between Wetmore and F. N. Chasen, regarding the disappearance of the throat sac in male frigatebirds in the nonbreeding season (Wetmore, 1938).]

shrinks steadily and fades from red to orange in color. I found in one that the pouch could be extended only one fourth as much as in a breeding male. The balloon in a mating male showed slight scratches, apparently made by contact with the sticks of the nest. For further notes see records of dissection. Seen harrying Wedge-tailed Shearwaters, seizing them by one wing and turning them over. One poor little *Megalopterus* half grown found on the ground a few feet from its nest had a bad wound in the head from the same source.

May 3. Several fresh eggs taken. May 4. In the large colony south of the lagoon 150 dead have been reported. I examined about 50 today---the others had been buried in sand---and found most of them immature. I believe that they have been killed during a storm and not by human agency as supposed by others. Collected a series of immatures. In the first plumage the head is white. A molt then brings brown in on the throat and later on the head. Sexing these immature birds requires care and experience. The ovaries in the female are very small, much flattened, dark reddish in color, closely applied to the kidney; they are shaped and colored like little leeches. The first one that I examined had both right and left ovaries persistent. Testes in the male are very small.

May 5-12. Seen harrying boobies and shearwaters. May 13. A young bird not more than 24 hours old taken from one nest. Nearly naked, purplish in color, skin smooth and shiny, eyes open, a few tufts of white down show on the back of the head, a few more on the sides of the thighs and over the tibiotarsus and on the humeral tract with a fringe along tail, posterior margin of wing as far as elbow, and posterior margin of alula. Active but wholly silent. About 30 mallophaga clung to the axillar region and the groin where the skin was punctured by their bites.

Dissection of pouch in adult male. May 2.

One individual mating with pouch fully developed was killed, the body inflated through the trachea until the throat balloon was fully distended. Another incubating male with pouch shrunk to 1/4 full size was treated in a similar manner. The first I opened along the back of the head and skinned carefully down on either side. The cells beneath the skin were felt to be fully inflated and at the first cut the pouch began to deflate until it was limp. A long canal led up from in front of the breast into the pouch but on this specimen I was not able to determine the opening below. There was no indication of an opening from the trachea direct into the pouch. Large veins led from the pouch to the neck, all distended with blood. These divided all over the surface of the sack and though pigment is present, blood imparts more than half of the red color since in this specimen, laid on its back, the color paled appreciably as blood drained out from the capillaries in the veins. In the second bird I removed the skin as usual in the preparation of specimens. The pouch deflated at the first cut into the cells on the abdomen. On skinning forward I found a passage at the shoulder on the inner side of the external (distal) end of the furculum, where an air canal led out from the thoracic cavity, enlarged and turned down to open into a single elongate canal that enlarged and led forward beneath the trachea to terminate in the pouch. This bird had a single testicle as usual on one side, one of similar size opposite to it and attached to one end closely a smaller one. A distinct case of triorchism, the first I have seen. Truly a bird for the ancient Greek augurs.

Ocean Island

April 17-19. Common. About 100 pairs nest in the *Scaevola* at the northern end of the opening. One male zigzagged through the air with the full pendant pouch blowing wildly in the wind while he uttered a mellow purring rattle. They frequently hang in the

wind over camp eyeing the human activity below curiously. April 20-22. A pair taken. They all nest in a close colony near the meadow.

Midway Island

April 23. A colony of 50 pairs nesting in *Scaevola* on Eastern Island. One taken. April 24. Sailing above Sand Island.

Pearl and Hermes Reef

April 26. About 150 nest on low spreading shrubs on Southeast Island. Nests were empty or contained one egg. Gray-backed Terns nested immediately below them in some cases. April 27. Seen on Grass Island but not nesting there. 80 pairs breeding on Seal Island. April 28. On Southeast Island.

Lisiansky Island

May 16. A number have nests in which the single egg is laid on the summit of a tussock of grass without other nesting material. The birds were very wet early this morning from the heavy rain of last night and rested with wings spread in an attempt to dry themselves. They flopped off across the grass over terns and boobies, some of them unable to rise, when I threw them into the air they flew, however, without difficulty. One male on a nest protested my approach with a high pitched drawn out "Kah-h-h". One drove two Blue-faced Boobies into the sea in evening. May 18. Abundant. Eight came at night to rest on a frame put up to dry seal skins so anxious are they for elevated perches. The birds rise from the nest heavily and many times throw eggs or young from the scanty nest platform. I have seen two nests here containing two eggs but in both instances one egg appears older and more stained than the other. I assume that one egg was deposited and then deserted for some reason or other and that then another female laid in the same nest. May 19. Many spend much time in circling high in air. About 80 pairs nesting here now with probably 500 additional birds roosting on the island.

Gardiners Island

May 22. About 125 pairs. One taken.

Nihoa Island

May 24-26. Many robbing Wedge-tailed Shearwaters and Blue-faced Boobies. June 12-16. About 600 pairs present. Only one male frigatebird was seen with the throat balloon distended. Others were incubating or had young and the throat sac had shrunk to a small size. Young ranged from newly hatched to a few birds half grown. The tertials begin to appear when the chick apparently is three weeks old and grow rapidly, perhaps to aid as a protection against sun. When undisturbed old and young rest with heads hanging down and backs to the sun to obtain what relief from the heat they may. At an early age the young appear pugnacious and extend the head and rattle the bill with a clattering call when approached. Hippoboscid flies swarm about the nests, 25 or 30 being often seen at once. When the birds are disturbed these insects fly about, frequently alighting in my hair. Nests were built of small sticks in the tops of low bushes.

Necker Island

June 17-19. Common. Nests contain eggs or young to 1/3 grown. June 20. About 300 pairs on the island. June 22. See journal. June 29. No change.

French Frigate Shoals

June 22-23. King Island. Three or four roost on the island. Others pass during the day. June 27. 60 pairs with eggs or young on Whale Island. Two had nests of sticks built up like a turret nearly three feet tall.

Kaula Island

July 1. At least 5000 rose from the high slopes at a blast of the TANAGER's whistle.

Johnston Island

July 10-19. Abundant. A few males are pairing and exhibit the inflated gular sac. Some few have eggs but the majority have young already on the wing. Birds able to fly are in many cases still fed by the parent. As the young bird sees the adult approach, it spreads its wings and utters a begging call. The parent after circling past several times alights on the ground and opening the mouth regurgitates while the young bird plunges its bill down the parent's throat to seize the food. After feeding, the old bird flies out over the water and swoops down to dip its bill and wash out its open mouth. A flock of these birds may be attracted easily by throwing small fish in the air, when the great frigates swoop and circle about often seizing the fish in the air. When one secures such a morsel others pursue it and frequently snatch the fish from its bill. It usually happens that they wrangle until the fish falls into the water and is lost. I see them pursuing terns, Wedge-tailed Shearwaters and boobies, often driving the unfortunates down into the water. The young come down to examine curiously a projecting pole and bite at it with their large beaks as they hang before the tip. At nightfall they gather in flocks to roost on the eroded ledges on the beach. They sleep with the head turned on the back but often spend an hour or more after dark in the care of their plumage. The adult female has a dull red rim around the eyelid. In the male this is black. Many are now molting extensively so that the beach is strewed with their feathers. The birds remain active at night and are continually overhead. 800 on Johnston Island, 100 on Sand Island.

Wake Island

July 27 to August 4. 2000 or more are found. A few have partly grown young in stick nests placed 8 or 10 feet from the ground. The majority however are not nesting. When not resting in the low trees they spend much time in soaring overhead. I see them pursuing terns and boobies. Rather wild and difficult to approach. Many were killed by the Japanese poachers.

Masked Booby *Sula dactylatra*
(Blue-faced Booby *Sula cyanops*)

Laysan Island

April 8-12. Scattered birds are found over the island, usually where some faint trace of vegetation remains. The majority are incubating one or two eggs or have young, though I have seen no young more than a week old. The parents are very solicitous and only edge away from their eggs under protest, while they are even more loathe to forsake their young. It is usual to see one bird covering eggs with the mate standing close beside and both join in protests at any intrusion. May 2. Some with eggs and some with young. As the birds rest on the nest they turn about with the long tail scraping on the sand. This forms a ring with the egg at the center, a slight depression about 30 inches across. May 3. The fish swallowed by these birds are truly enormous and frequently measure 10 to 14 inches long. May 4. A bird in second year plumage taken. May 5. Some have eggs in the nest while other have well grown young. One sheared the end from my thumb with a single clip of its bill. May 7. Birds that have no nests remain still in pairs in some cases. They are very attentive to their young and remain always in guard near them; when driven away they soon return. May 8-12. New pairs are coming in to nest in different localities. I took one egg that was fresh but had the misfortune to break it. May 13. A young bird less than 24 hours old did not have the eyes open. It is already covered with a sparse growth of white down and uttered a low wheezy call. The adult female in addition to being larger than the male has the bill and feet slightly duller, less yellow.

Ocean Island

April 17-19. Common in the open space at the northern end of the island. The birds are nesting here on the ground where they have scraped away the vegetation and deposited two eggs on the bare soil with no nesting material. Some have young two weeks old. The male frequently rests near his mate. As I approach they greet me with protesting squawks leaving their eggs with evident reluctance sidling awkwardly about near at hand. At camp they pass frequently to or from expeditions for fish. About 200 pairs present. April 20-22. These great birds were nesting wholly on the ground. They are much agitated at near approach but seldom show much fear.

Midway Island

April 24. Two seen on Sand Island.

Pearl and Hermes Reef

April 26. On Southeast Island about 50 pairs are nesting in areas on the sand beaches or on the bare eroded limestone at the eastern end. They do not colonize in the strict sense of the word, as they are scattered over considerable areas. Caum has called my attention to the fact that the voice of the female is a harsh quacking squawk uttered loudly, while that of the male is high-pitched and whistling. When disturbed they frequently regurgitate large flying fish. April 27. Seen flying over lagoon. April 28. The steady wind was banked in the water on the eastern end of Southeast Island and I found one booby nest in a little depression flooded out. The female still sat on her single egg, though it was under an inch of water. One bit my thumb nearly to the bone in a single bite today.

Lisiansky Island

May 16. Fairly common. Some young here are as large as adults. May 18. Several young on the island are fully grown and able to fly. One taken to show the dark head. Some of the adults are now mating and choosing nest sites. They stand near one another, point the bill up, and then wave the head and neck about with a silly expression

that is very ludicrous. One of the parents is nearly always on guard with the young at the nest. May 19. About 100 pairs on this island. All nesting on the ground though mainly concentrated near the grass plot. May 20. Several pairs seen resting on the open sea near one another.

Gardiner Island

May 22. This booby was the most prominent of the larger birds. About 400 pairs nested on the island. Nesting varied from birds that had just selected breeding sites to others that had young on the wing. Perhaps half had well grown young. For nest sites the birds congregated on the upper third of the island where they were so numerous that their excrement formed whitish or yellowish coatings over the black volcanic rock that, as we came in the first evening, appeared light as snow. Progress up the slopes was along the ledges appropriated by the birds and at every step we were greeted by harsh squawks, piping whistles (males) and threats with open mouths. Where the birds had well grown young they often attacked us, waddling up to deliver a severe bite and at all times were fearless. On many ledges where passage was narrow it was necessary to clear the birds away to avoid possible attack that might lead to a fall. We slapped them with our hats and pushed them with our feet while they struck and resisted with great turmoil often only when literally pushed over the edge of the rock when they had to take to their wings.

Nihoa Island

May 24-26. Though scattered Blue-faced Boobies nested in occasional small open spaces over the island, the majority were gathered in a scattered colony on the little depression below Millers Peak. They had young here from newly hatched to birds on the wing. As elsewhere, flying fish seemed to be their main food. I estimated their number at 125 pairs.

Necker Island

June 17-19. Common over the higher slopes of the island where they have young from half to nearly grown. When undisturbed the females and young frequently utter their loud quacking calls in a contented tone. June 20. About 500 pairs here. June 29. A fine big female seen anxiously guarding a runt egg the size of the egg of a Bulwer's Petrel. Her attempts to roll this tiny egg about were very funny.

French Frigate Shoals

June 22-23. About 30 pairs on Round Island, 150 pairs on King Island. All have large young. Anderson claims that one egg is infertile and that he has seen the parent feed it to the newly hatched young. I saw one here attempting to feed a well grown young. The "chick," a mass of down nearly as large as its parent, crouches with waving head nibbling at the parent's bill. The latter finally opened the mouth and extended the neck while the young thrust its bill down the capacious opening as far as possible to seize a large flying fish by the tail and draw it up. As the tail of the fish protruded from the adults mouth the youngster lost his hold and the coveted food was promptly swallowed again. This process was repeated half a dozen times before the exchange was made. An adult swallowed two fish 8 inches long that George the cook handed to it. Males frequently waddle off and then raising tail and wing tips elevate the bill in the air and emit a reedy sighing whistle. After repeating this for the edification of the female several times they came waddling back to the youngster with an absurd manner of anxious solicitude. June 24. 8 pairs with well grown

young on Little Gin Island. One dead young seen. June 26. 20 pairs on Trig Island, 40 pairs on Skate Island, 70 pairs on Whale Island, all with well grown young. June 27. 20 pairs on La Perouse Rock. June 28. 8 pairs on Tern Island.

Kaula Island

July 1. Seen.

Johnston Island

July 10-17. Common. A few pairs still have young in the down but the majority have completed nesting. A small number roost at random over the island. A flock of one hundred adults gathers each night at dusk on a rock ledge on the eastern shore where they roost closely together like cormorants. Young in first plumage are fairly common. One or two pairs still have eggs. About 200 on Johnston Island. 20 on Sand Island.

Wake Island

August 2. Two young and one adult shot on the windward side of Wake.

Brown Booby ***Sula leucogaster***
(Common Booby *Sula leucogastra*)

Laysan Island

April 10. One seen by D. R. Dickey in the surf. April 29. One pair have a nest east of the lagoon near the *Sesuvium* patch, apparently the first record for the island (not so, noted by Schlemmer.) May 5. Bird seen on nest. May 7. Male seen on nest.

Ocean Island

April 17-19. Fairly common. Probably 50 pairs present. The birds are nesting in the opening near the northern end of the island. The nests are placed on the ground in the open and are slight mounds of dead *Scaevola* stems mixed with green leaves of "*Baccharus*" all apparently gathered within a radius of a few feet. Nests contained one or two eggs. some of the latter were hard set. These boobies were rather wary and usually rose when I came within gun range to scale back and forth in the wind. In the male the face and gular sac are purplish blue while in the female these areas are bright yellowish green, characters that distinguish the two readily. The eyes do not differ in the sexes. Occasional individuals scale out over the beaches. One, when killed, regurgitated a blue flying fish. April 20-22. Fairly common as indicated above. The reef on the western side of the island approaches within 100 to 300 yards of the beach. These boobies seem to feed mainly on this side of the island and comparatively few are recorded on the opposite shore where we have our camp. They approach readily within gun range but are much wilder than the other two species.

Midway Island

April 23. A dozen seen, including one in first year plumage. One taken. Birds found along beach.

Pearl and Hermes Reef

April 26. About 10 pairs nest on the ground on a bare area of eroded limestone rock on Southeast Island. Nests were made of bits of grass arranged to form a mat with a slight depression at the center. Eggs invariably two. Have seen one nest with a small young. April 27. Seen flying over the surf. April 28. Recorded on Southeast Island.

Lisiansky Island

May 16. A number of pairs nesting in grass tracts have eggs, new hatched young to young 10 days old. An immature molting into adult plumage taken. The present species is less noisy than *cyanops* or *piscator* and even on the nest ordinarily is silent. A female today however uttered a loud "quok quok quok". May 18. Fairly common. Mr. Thaanum brought in a five inch flying fish of the common species, one of five regurgitated by one of these birds. May 19. About 40 pairs on this island. A pair taken today. Nests contain 2 eggs, sometimes newly hatched young. One or two seen that contained young ten days to two weeks old, one young in each instance. Part of the nests here are located in the grass, on the ground in spaces between the clumps and part on bare ground on a slight elevation near the eastern side of the island.

Gardiners Island

May 22. Several reported a single booby on the small western rock.

Nihoa Island

June 11-16. About 50 pairs nest on the island, most of them on open ledges above the cliffs 50 to 100 feet above the sea. Theses boobies are much more wary than the other species and may seldom be caught by hand. I have seen one nest containing two eggs but most have young, many of which are half grown. These stand about on the rock ledges and are afraid, so that they attempt to sidle away when approached. One at camp maintains a precarious perch on the very edge of a rock projecting over a precipice and several times has slipped and almost fallen as it moved about. Another farther on slipped, fell, and was killed on the rocks below. In the warm morning sun one sometimes sprawled out on a rock ledge with wings flat at its sides to bask in the sun.

Necker Island

June 17-19. A few seen on the lower rock cliffs. One or two half grown young recorded. June 20. About 50 pairs inhabit the ledges on the rock cliffs.

French Frigate Shoals

June 22. King Island. Two seen and one taken. June 24. One on spit near Round Island. June 27. About 30 pairs seen on La Perouse rock.

Kaula Island

July 1. Seen on cliffs.

Johnston Island

July 10-17. Common. A small part of the birds now have young from two weeks old to birds on the wing. Adults are wary as usual and when resting prefer perches off shore on projecting rocks where they can take flight at the least indication of danger. Numbers come to the island to roost at night but are much more wary than others and usually fly before they can be approached. Some have young from two weeks old to nearly able to fly. These young delight to climb about on rock ledges where they perch easily on pointed stones. They are decidedly uneasy when approached and attempt to hide. Adult females at the nest sidle about with loud quacking calls and if disturbed too much take flight heavily. Nests seen are all on the ground. About 75 on Johnston Island.

Wake Island

July 27-August 4. There are fully five hundred here, mainly found on the windward side of the large island. On the western end of the north half of Wake a few pairs have young from half to nearly grown in ground nests. Other pairs rest in perches in the trees and apparently another breeding season is approaching. At evening many of the birds beat in to the island from some fishing ground to the southwest and pass low over our camp. Many are robbed by the frigatebirds. On the windward side of the atoll the birds rest on logs or lumps of coral, frequently in little groups. They are much more wary than other boobies. Like the other species they fly with neck outstretched and feet straight behind. The flight is strong. Their heavy necks slope gradually into the long slender bodies.

Red-footed Booby *Sula sula*
(*Sula piscator*)

Laysan Island

April 8-12. Small colonies occupy two low bushes where they have constructed stick nests that now contain eggs or small young. The birds bristle defiantly and strike viciously at any intruder. They have been more or less disturbed since our arrival and eggs of a number have been destroyed by the finches. A curlew stole one. At night birds not on the nest sleep on the ridge of the buildings on old frames or on the fronds of the two coconut palms, sleeping with head securely tucked under one wing. May 2. Many eggs still unhatched. May 3. A bird in full immature plumage seen. Schlemmer caught it at night. May 4. Seen carrying nesting material. At night I inspected the colony in the ironwood by aid of a flashlight. The birds slept soundly with head way back under the wing and when disturbed merely blinked sleepily and then went back to sleep. Males in some cases rested on branches an inch or two from the nest. May 5. Two immature birds shot this evening from roosts in the coconut trees. They come in here at night to rest from their fishing excursions. Nesting birds do not seem to resent having these young come to rest near them. May 8. Heard their harsh calls at intervals during the night. May 9-12. The call of the male is distinctly higher pitched than that of the female. In addition his gular sac is black, while that of the female has a bluish tinge. Either male or female remains on the nest constantly day or night. Another young bird has hatched. They grow rapidly. May 13. A number of nests seen were placed on the ground about the stems of old tobacco plants. Made of a collection of twigs twelve to fourteen inches long. These nests contained one egg or were empty. a number were still under construction. An immature taken was molting into second year plumage. These young birds rest about on the nests of the adults without protest in most cases.

Ocean Island

April 17-19. The present species nests in the *Scaevola* bushes that cover the island and is the most abundant of the three boobies as about 1000 pairs are present. Many have not yet chosen sites for nests but are merely resting. April 20-22. As I stand on the higher dunes and look out across the dense growth of *Scaevola* the green of the shrubbery here and there is punctuated by the spots of white made by these boobies as they rest quietly on the branches. Seldom are more than half a dozen gathered in one place and in only one or two localities are small colonies of a dozen to twenty pairs found. They seem not to follow their usual gregarious habit on this island. A few have eggs now but the majority are either nest building or choosing nest sites. I observed two prospecting among the branches until they found a spot to their liking. Their search was made with many posturings in which the wings were partly spread and quivered and the bills pointed up and waved about while they uttered uncouth wheezing calls and sidled awkwardly about on the small limbs. The birds pass camp continually to and from their fishing excursions. Two only in immature plumage were noted, one of which was taken.

Midway Island

April 23. A colony of 25 pairs nesting in bushes on Eastern Island. One taken.

Pearl and Hermes Reef

April 26. About ten pairs nest on clumps of grass on Southeast Island. Nests contain eggs or young.

Lisianski Island

May 17. Tonight with the flashlight I came across 25 of these birds gathered closely together to roost in the grass plot. May 18. Two nests containing eggs found in the grass plot. The single egg was laid in the crown of a grass tussock without other nest material. The embryo from one preserved. May 19. About 40 inhabit this island. Most of them are not breeding now and seem to spend the day at sea. At night they came to roost in the grass plot or on stakes at the old Japanese camp.

Gardiners Island

May 22. A dozen circled about at daybreak on their way from a roost on the island. None seen on shore.

Nihoa Island

May 24-26. Seen frequently. June 11-16. Numbered about 3000 pairs. These boobies ranged over the entire island, grouping at times in little colonies and again spreading over broad areas of hilltops. In looking across the valleys their white forms showed everywhere as little spots. Their nests were built on the tops of low spreading shrubs three or four feet from the ground and were broad, flat structures of small twigs and sticks 2 to 3 feet across with a shallow depression in the center lined with a few green leaves plucked from adjacent shrubbery. The birds laid but one egg. Many nests were newly constructed, others contained eggs from fresh to heavily incubated and young in others ranged from newly hatched to half grown. A few birds found nesting sites in the crests of the palms (*Pritchardia*). The adults were amusing in their movements. As I

approached they turned to face me with ruffled feathers and reached out constantly with necks fully extended as though to strike. When really threatened they squawked loudly and flew. I saw one preening a young bird attentively, working carefully through the down on its back. One bird in gray plumage with a pure white tail flushed from a nest containing a newly hatched young bird.

Necker Island

June 17-19. Common. Nests in some cases are just built. A few contain eggs and the majority young one third to half grown. I saw one young bird almost adult with only a trace of down on the head. There is something decidedly serpent-like in the appearance of the adult as they protrude and retract their necks when disturbed. June 20. About 1000 pairs here. June 22 (see journal). June 29. No change.

Figure 48. A Red-footed Booby alighted on the shoulder of George [Higgs], the cook. Tern Island, French Frigate Shoals. June 26, 1923.

French Frigate Shoals

June 22-23. King Island. About 20 roost on the island. Thaanum while working on the reef in early morning had one alight on his head and remain there until he tweaked its tail. June 26. One pair on Skate Island, 15 pairs on Whale Island where they nest in the tops of *Chenopodium*. Some have eggs while others have nearly grown young. A bird a

year old alighted on George Higgs' shoulder as he sat waiting for the boat one evening. One adult seen brooding a young frigatebird. June 27. 30 pairs at La Perouse Rock.

Kaula Island

July 1. Abundant over high slopes.

Johnston Island

July 10-19. The most abundant species. Few are seen at day but at dusk bands gather to spend the night on rock ledges along shore. They rest in social groups almost rubbing wings and sleep with the head turned on the back. Often I find them engaged in the care of their plumage long after dark. The great majority are young in first or second year plumage. Have seen only half a dozen white adults. They protest examination by flashlight with harsh croaks but do not seem greatly alarmed. After three or four nights disturbance, however, the majority moved to Sand Island. One bird with a single egg on a ground nest.has an indistinct dark band on the breast and a white tail. I examined all grayish birds seen for those with white tails but failed to find more. Frigatebirds rob these poor birds unmercifully while the boobies flee with protesting squawks. When not loaded with food the red feet mingle freely with flocks of their larger neighbor as they soar in the steady tradewinds. About 250 on Johnston Island. There are six nests containing eggs there.

Wake Island

July 27-August 4. The Red-footed Booby is, next to the noddy, the most abundant species of bird here, as it numbers at least 5000, perhaps many more. The birds are so scattered through the trees that it is difficult to get a true idea of their number. They are distributed everywhere but are most common around the shores of the lagoon where they gather during the day in parties on the open limbs of the umbrella trees in companies. Preferred perches are those exposed to the gentle sweep of the east tradewinds. The birds preen or sleep here or rest quietly in the sun. When approached in the open they usually fly when I am some distance away but when I come on them suddenly in the bushes they seem wholly unconcerned. No occupied nests have been found but many of the adults have chosen nest sites among the trees and are beginning nesting antics. One rests below the other and utters a peculiar drawn out wheezing call while it throws the head up and the neck back and waves around in the air. At other times the two rest near one another uttering low clucking calls.

The birds delight in soaring overhead in the strong breeze when it is a delight to watch them. With spread wings they swing back and forth often in company with their enemies the frigatebirds now bent on the same pleasures. When I startle the boobies from perches in the bushes 8 or 10 feet from the ground, they frequently flop out heavily and fall to the ground without being able to gain sufficient headway to rise from the ground. At evening bands of the boobies come in from the sea toward the southwest, beating steadily toward the island. Many are intercepted by frigatebirds and often are forced to disgorge. Other boobies flying low and swiftly gain shelter of the trees when the frigate gives up the pursuit. The broad-winged tyrant flaps steadily along above its victim, following its twisting flight with the greatest ease. If the booby does not give up forthwith it is usually seized by the tail and shaken while it squawks protestingly. At camp we amuse ourselves as the boobies pass overhead by imitating their raucous call, when they flare and dodge in consternation, never looking below but peering behind for their supposed pursuer.

Laysan Duck *Anas laysanensis*
(Laysan Teal)

Laysan Island

April 8-14. It was with great relief that I saw three of these teal on my first day afield on Laysan, as I had feared that they were extinct. They were found near the *Sesuvium* patch and once in a while in the tobacco patch. Seventeen were noted at one time.

April 30-May 5. Reno has reported seeing 20 at one time and today I was able to verify this. The birds were spread out over rough ground among rocks and were roosting or sleeping. A number were divided off into pairs, others remained four or five together. When approached they waddled slowly away. When hard pressed they flew but seemed rather heavy on the wing.

May 6. This evening I went out and caught four teal with a flashlight and a dip net. As dusk came on the birds walked out for a quarter of a mile across the flats to a little lagoon where after dark they found feeding along the margin. The call note of the males is a high-pitched tremulous whistle, trilled to some extent and unlike that of other teal known to me. The female utters a high-pitched quack.

May 7. This morning the teal were back again among the rocks where they were resting quietly asleep or preening their feathers. Schlemmer and I ran down and caught two males. They were able to fly for a distance of 125 yards aided by the wind which helped sustain them but then dropped to the ground and began to run. I find that they show the effects of inbreeding as the feathers of the wings in some are imperfect or missing. In one case three primary quills had developed the butts only and lacked the shafts and webs, while one female lacked most of the breast contour feathers. The nasal gland above the eye in these birds is considerably larger than usual in Anatinae of this size. The feet are remarkably large. The birds were not at all alarmed by our pursuit and returned at once to a station within 60 yards of us. Males have the testes fully developed but penis small, females will lay in two or three weeks. They are usually found divided off in pairs.

Male adult. Line of culmen for width between nostrils, nail, and base of lower edge of maxillary tomia dull black; a faint slaty gray band across tip of bill behind nail; rest of upper mandible dull olive gray; lower mandible mouse color, nail storm gray. Web between rami dull orange brown mottled with blackish; tarsus and toes orange brown, mottled with blackish. Tarsus and toes orange, nails fuscous. Iris Van Dyke brown.

Female adult. Upper mandible dull blackish with a faint orange wash on sides, a faint slaty gray band across tip; lower mandible dull orange brown, nail fuscous; iris bone brown; tarsus and toes dull orange; nails fuscous.

May 8-13. Seen as usual sleeping during day or feeding in small lagoon in evening. May 12. While on the big lagoon on a raft two circled past on the wing examining me curiously.

[On a small note sheet is the following interesting bit of information evidently relayed to Wetmore by someone on the expedition.] Laysan Teal. 24-25 brought to Honolulu by Geo. D. Freeth about 25 years ago released by Mr. Whitney in the Kewalo

marsh in the outskirts of Honolulu. Birds strong and flew well but none taken since. Released in 1894.

Northern Shoveler ***Anas clypeata***
(*Spatula clypeata*)

Laysan Island

Eric Schlemmer tells me that in November or December 1916 he killed one of these ducks, unmistakable because of its broad bill, in the lagoon. Wild ducks of two kinds are reported to occur here.

Wake Island Rail ***Gallirallus wakensis***
(*Hypotaenidia wakensis*)

Wake Island

[Several times in his account of this species Wetmore refers back to his journal, with the following being the only other entries.]

July 31. None found on Peale Island.

August 2. These birds seem very sedentary. Those that I take on sandy areas where there is only scattered areas of shade, are very worn and pale color above, those from certain sections where there are extensive dead-falls have the wing feathers worn and abraded, apparently from their use in climbing about. This is true though more suitable areas where conditions are less severe may be found near at hand. The wing claw in this species is very large and strong.

[It is clear that Wetmore was not aware of this endemic, flightless species when he arrived at Wake. In his temporary field catalog it is only entered as "rail" in pencil. The species had been described twenty years previously as *Hypotaenidia wakensis* (Rothschild, 1903) in a very short note in which it was stated that "a Japanese vessel obtained ten specimens in 1892". This may very well have been the only mention of the species anywhere in the literature prior to the TANAGER expedition, and so might easily have been overlooked. I have assembled new information from archives and specimens on this species, which I will present in a separate publication.]

Laysan Rail ***Porzana palmeri***
(*Porzanula palmeri*)

Laysan Island

April 8-13, 1923. One or two mummies found only. April 29. Eight brought from Midway released in the *Sesuvium* patch. Two have been seen since my departure, one in the guano piles and one on the *Sesuvium*. April 30-May 13. One or two seen at intervals. Two observed May 12 and one May 13, the latter one at the guano piles. A number of mummies have been found, two of these, probably three, bodies of those brought from Midway. The survivors run in and out of holes in the rock piles.

Midway Island

April 22-24, 1923. These tiny birds are abundant on both Sand and Eastern Island where they run about familiarly in the brush. Mr. Axelrod told me that originally they were found only on Eastern Island but that about 1906 he brought some over and released them on Sand Island where they are now abundant. They are alert, self-reliant little fellows that came peering out from under the branches of *Scaevola* at me as I sit on the ground or chatter with a loud scolding note from cover. They walk about with long nervous steps or run rapidly across openings. At full speed the wings are opened and flapped wildly but no attempt is made to fly. We ran down and captured a number. When held in the hand they did not seem particularly alarmed but bit and struck at one another viciously when two were held within striking distance. They fought when at freedom, too, and the victor drove the conquered one about from place to place chasing it for yards and yards. They came frequently to feed with the chickens.

Asiatic Golden Plover *Pluvialis fulva*
(Golden Plover *Pluvialis dominica fulva*)

Laysan Island

April 8-13. Fairly common. Many dead birds lie strewn about and I suspect from alkali poisoning from the inner pools on the island. May 2. Fairly common. Many died here in the sand storms during my absence. Bodies scattered everywhere. These birds have been seen eating eggs. May 3. Several. May 4. Twenty or more. May 5. Two or three hundred. May 6. Common. At night under the light of a searchlight these birds seem entirely dazed and though they may run about may be picked up with ease. They do not struggle nor do they make any outcry. May 7. This evening I caught one as it came at dark toward the shacks seeking a sheltered place for a night's sleep. It rested quietly in my lap for fifteen minutes while I sat talking in the dark with one of the men, seeming to enjoy a gentle scratching in the feathers of its neck. I placed it beside a box in the bird room where it was sleeping quietly an hour later. Many in a thin, weakened condition are about and hundreds have died. I attribute their trouble to the heavy alkali in the lagoon water. May 13. Several hundred feeding in the lagoon. Some in full breeding plumage and other in winter dress.

Ocean Island

April 18. A beautiful bird shot running about among the plant-covered hillocks in the center of the island in company with turnstones. April 19. Several. April 20-22. Fairly common. Found in the little meadow with turnstones and also on the beaches. At night they cross to the beaches to roost.

Midway Island

April 23. A few on Eastern Island. April 24. Common on Sand Island where it frequents the beaches and comes to the lawns at the cable station. Many seen in nearly full breeding plumage. Others in transition from winter dress.

Pearl and Hermes Reef

April 26. A few on Southeast Island. April 27. A few on Grass and Seal Islands. April 28. A few on Southeast Island.

Lisiansky Island

May 18. One. May 19. A flock of a dozen seen.

Nihoa Island

June 11. Three seen on the rocks of Adams Bay.

Necker Island

June 20. One taken.

French Frigate Shoals

June 23. King Island. About 20 seen. June 24. Three passed in northern flight. A few seen are in breeding plumage.

Johnston Island

July 15. Two seen and one taken on Sand Island. Not in breeding state.

Wake Island

July 30. About 200 feeding on rock flats laid bare at low tide. Very wild. August 1. Four. August 2. A dozen seen. August 4. Common in southward migration. Found in little openings among the *Tournefortia* trees.

Wandering Tattler *Heteroscelus incanus*
(*Heteractitis incanum*)

Laysan Island

April 9. One taken. April 10. One seen. April 12. One. May 2. Flocks of 10 or 12 found on limestone ledges near blowhole. Birds feeding and resting. About 50 seen today. May 3. About 20 on a stretch of rock ledge. May 5. Common. May 6. Seen. May 7. Seen. May 13. Common both along rocky shore and at the lagoon.

Ocean Island

April 19. One shot on a sandspit. April 20. One. April 21. Two seen. These birds are much more difficult to approach than the other shorebirds.

Midway Island

April 23. One taken on Eastern Island.

Pearl and Hermes Reef

April 26. One on Southeast Island. I found a dozen or fifteen in a flock on the bare lime rock at the eastern end. Two taken were in full plumage. April 27. A few seen on Grass and Seal Islands. April 28. Seen on Southeast Island.

Lisiansky Island

May 16. Two seen, one taken. May 18. Seen. May 19. Four seen, one taken.

Gardiner Island

May 22. One or two running about on rock ledges near the water.

Nihoa Island

May 24. Two or three seen. June 11-16. One or two seen daily on the rock ledges of Adams Bay.

Necker Island

June 19. One taken was molting the outer primaries. One or two seen daily from 17 to 19. June 20. Seen. June 29. Seen.

French Frigate Shoals

June 22. King Island. One. June 27. La Perouse Rock. Two seen.

Johnston Island

July 11. One taken. July 13. One taken. Both above are non-breeding birds.

Wake Island

July 31. Two seen. August 1. One.

Bristle-thighed Curlew *Numenius tahitiensis*

Laysan Island

April 8-13. Common over the entire island, found singly or in little groups. Several came about camp and before my departure were running tamely about before the door of the skinning room in search of scraps of fat thrown out during the preparation of sea birds. Like the turnstones, these curlew are devils after tern's eggs, driving the bill into the eggs at every opportunity and running away with the egg impaled to eat it at leisure. One even flew up to a Red-footed Booby nest in a bare bush beside the cook shack during the momentary absence of the brooding parent, impaled the egg and dragged it off to be devoured. The poor booby was still brooding disconsolately on the empty nest two days later. I saw one curlew deliberately open an old albatross egg and eat from the putrid interior. As this egg had probably been lying in the sun since December, its condition may be imagined, yet the curlew was so anxious for its repast that it returned time and again, though I approached within 10 feet. May 2. About 30 seen. A dozen were working about among the Gray-backed Terns in search of eggs. Dickey saw one seize a frigatebird egg when the parent raised and exposed it, though the frigate did not leave the nest. The curlew carried the egg off in its bill without breaking it. A good many curlew found dead or sick. May 3. Three seen. May 4. Two. May 5. About thirty noted. May 6. A number picked up this evening while out with a flashlight. May 7. Seen. May 8. Seen. May 13. About 30 seen today. Often seen in small flocks.

Ocean Island

April 17-19. Several seen. April 20-22. A few noted at intervals. One taken.

Midway Island

April 23. Several seen, one taken on Eastern Island. April 24. A few on Sand Island.

Pearl and Hermes Reef

April 26. One taken on Southeast Island. April 27. Seen on Grass and Seal Islands. April 28. Seen on Southeast Island.

Lisiansky Island

May 16. Two seen. May 18. One. May 19. Four seen feeding along the beach. One taken was pulling and shaking at shreds of dried flesh on an old tern skeleton.

French Frigate Shoals

June 22. King Island. Eight seen, two taken. Not in breeding condition. June 23. Several seen. June 24-27. One or two seen daily.

Wake Island

July 28. One taken from a flock of 3. July 29. Two seen. July 30. Seen. July 31. Two seen. August 1. A female in fine adult plumage taken. Showed black atrophy of the ovary. August 2. An adult male taken in full plumage had small sexual organs [sketched oval 2 x 4 mm].

Ruddy Turnstone *Arenaria interpres*

Laysan Island

April 8-13. Common about the inner lagoon and on the sand beaches. There is migration on among the birds at present and I note variation (considerable) among their numbers from day to day. Many are first assuming nuptial plumage. Like some other birds the turnstones here shows some hitherto unsuspected traits. In the tern colonies I find them very destructive to eggs so that I had some difficulty in securing perfect eggs for specimens. At first I supposed that they were eating from eggs opened by the Laysan Finches but on watching on numerous occasions I saw them deliberately drive their bills into eggs and begin to eat the contents. In fact there were always little scattered bands running about among the forming colonies of *Sterna lunata* waiting a chance to run in and pierce an egg. When my advent flushed the terns, the turnstones were not slow to profit by the opportunity.

May 2. Abundant. 75 seen in a mile on east and south shores. About 300 on lagoon. In a colony of Gray-backed Terns I saw two turnstones run in and pull an egg from beneath a tern and break it within six inches of the incubating birds. She looked about, moving her head uncertainly, looked beneath her breast, and finally reached over, took hold of the broken egg with her bill and drew it nearer to her. The turnstones

continued to run in and out and eat a little, afraid but still bold while the tern made no effort to protect her egg. I can see no chance for the terns to breed until these robbers go north. May 3. Abundant. May 4. These turnstones gather to feed on refuse at a pile of tin cans back of the cook house and also run about the door. Though attracted by flies, which are few in number, they also pick up bits of garbage. They also gather to look over the coral lumps that Mr. Thaanum brings ashore and cracks apart in search for mollusks, finding in these a rich harvest. May 5. A thousand or so now on the island. May 6. These birds are readily captured at night by means of a flashlight. May 7. Fifteen or twenty may always be found about the garbage pile back of the kitchen in search of scraps of meat or fat. May 8. A number have been seen that I suspected had died from alkali poisoning and today I examined one that showed all the reactions of the trouble, paralysis of nictitating membrane, and lack of control of feet, wings, and neck. May 9. Sick turnstone lies prostrate with head prostrate, barely breathing. May 13. Three or four thousand present on the island. Brine shrimp at the lagoon form attractive food.

Ocean Island

April 17-19. Common. I find the birds here working back under dense cover of *Scaevola* bushes to feed under cover far from the beaches. As I have been accustomed hitherto to see them on mud flats or beaches, it gave me momentary surprise to flush them from localities suited to woodcock. many in the grass grown central opening.

April 20-22. These birds regularly penetrate among the dense growths of *Scaevola* to feed. It is always a surprise to me, when squeaking to attract a possible land bird from among the bushes, to have a turnstone pop out and alight easily on the tip of a branch while it eyes me closely. Little parties remain in the central opening until after sunset and then fly across to the beach to roost.

Midway Island

April 23. Common on Eastern Island. April 24. Common on Sand Island where it frequents the beaches and also comes tamely about the lawns at the station.

Pearl and Hermes Reef

April 26. Common on Southeast Island. April 27. At day break two came beating up from the south, swung in toward the ship and then bore away to Seal Island. They seemed very tired and flew low over the water to avoid the steady shove of the trade wherever possible. April 28. Seen on Southeast Island.

Lisiansky Island

May 16. Four seen. May 17. Two. May 19. Three or four noted.

Gardiner Island

May 22. A flock of fifteen on the rocks near the water. One killed had just eaten a tern's egg.

Nihoa Island

May 24. Two on ledges below the western cliffs. June 11-16. One or two seen daily on the rocks of Adams Bay. Two seen resting on a cairn on Millers Peak 900 feet above the sea.

Necker Island

June 17-19. One or two seen daily. June 20. A male taken had small sexual organs. About 20 seen. June 21. Three seen.

French Frigate Shoals

June 22-23. King Island. About thirty seen. One taken on Round Island. June 24-27. Seen daily on Sand Islands [probably Gin and Little Gin Islands, which in the journal are referred to as "the eastern sand islands."]. One heard giving a low trilling song on the wing.

Johnston Island

July 15. Two seen and one taken on Sand Island. Not in breeding condition.

Wake Island

July 29. Two seen. July 31. Seen. August 1. A dozen seen. A male taken in adult plumage had testes [sketched oval 2 x 5 mm]. August 2. About 20 seen. August 4. Seen.

Sanderling *Calidris alba*
(*Crocethia alba*)

Laysan Island

April 11. Four seen and one taken. April 12. A dozen. April 13. Several. One noted by Schlemmer about April 23 (ask Dickey for actual date). May 2. One seen by Grant. May 4. Two with turnstones at the lagoon.

Ocean Island

April 19. One taken from a flock of four.

Necker Island

June 19. One reported by Grant.

French Frigate Shoals

June 25. Tern Island. One taken alone on beach.

Gulls *Larus* spp.

Ocean Island

April 17. Two mummies found on the southern end of the island.

Pearl and Hermes Reef

April 27. One picked up on Seal Island by Mr. Thaanum.

Necker Island

June 18. Body of one picked up by Grant on small beach.

[The above specimens of gulls, collected as mummies, were evidently kept in holdup for many years, as they were not cataloged until 21 June 1967. One of the specimens from Kure was identified as a Glaucous Gull (*Larus hyperboreus*) and all the others as Glacous-winged Gulls (*L. glaucescens*). These specimens were first noticed in the literature by Clapp and Woodward (1968). The specimens have since been skeletonized.]

Gray-backed Tern *Sterna lunata*

Laysan Island

April 8-13. Common. A series collected April 12 with eggs ranging from fresh to slightly incubated. The birds nest in colonies, choosing sites among small lumps of coral above high tide mark, the rough eroded surface of exposed limestone on the beaches or sand on little eminences above the beaches. One egg is laid with no nesting material. May 2. Because of ravages of floods and robberies of turnstone and curlew I cannot see these terns have succeeded in keeping any of their eggs. Conditions may be worse now because of migratory movement among curlew and turnstone than during winter when these marauders are stationary. May 3. This morning I examined the tern colonies along the northwest shore but of the many pairs that had laid here in early April, I found but three eggs remaining. Others had been destroyed by shorebirds or storms. The terns were still about but were not laying. May 4-5. Seen. May 6. In the light of a searchlight these terns seem dazed and many turn their backs making no attempt to fly. May 8. A colony have established themselves at the crest of the highest point at the south end of the island and now have many eggs. May 9-13. Numbers of fresh eggs of these birds are noted again and turnstones and curlew still work about the colonies. I have seen turnstones run in and pull an egg from directly under the parent, who made no attempt to defend herself. Though these birds form colonies they nest somewhat at random in the lee of bits of rock or drift, on blocks of stone, or on the open sand.

Ocean Island

April 17-19. Fairly common. April 20-22. A few pairs beat back and forth along the beaches. One taken was not quite in breeding condition.

Midway Island

April 23. A colony of 150 pairs seen on Eastern Island where they were nesting in an opening away from the beach. Many had already deposited their single egg.

April 24. A few on the beaches at Sand Island.

Pearl and Hermes Reef

April 26. About 300 pairs nest in scattered colonies on Southeast Island. Colony sites varied from the bare limestone rock to little openings amid clumps of grass. I found some under low spreading bushes with frigatebirds' nests 1 1/2 to 2 feet above them. The terns were so tame that I picked up several in my hands. Some had newly hatched downy young of which I collected one. April 27. 150 pairs nesting on Seal Island with eggs and newly hatched young. April 28. On Southeast Island.

Lisiansky Island

May 16. Found breeding in the grass tract and also in the open flats far from any cover. The majority of the birds now have young from recently hatched to well grown. May 18. Many eggs and young of this bird seen. They seem best suited for nesting locality in the grass plot. There the young, active almost from hatching, run about under shelter, safe from enemies and excessive sun. Those hatched in the barren flats must have difficulty in escaping the rapacity of frigatebirds. It is a pretty sight at night to see one hovering a chick with its mate resting wing-to-wing with it. The adults run about beneath the grass and may easily be picked up, as they get far back under cover, from which they call loudly when alarmed, as when on the wing. May 19. About 250 pairs here.

Gardiner Island

May 22. About 100 pairs nested on suitable ledges where some had eggs but the majority young. The youngsters from a week old up clambered actively up and down the ledges sometimes tumbling for a few feet but always catching themselves. May 23. Seen at sea north of French Frigate shoals.

Nihoa Island

May 24-26. Common. June 11-16. Abundant. About 5000 pairs nesting over the slopes clear to the summit of the island. The majority now had fresh eggs though some had newly hatched young and I saw a very few young about half grown. Where nests were gathered in colonies, sites were separated from one another by just a little more than reaching distance. Adults were circling noisily in the air throughout day and night and frequently clouds came flying out in company with other terns.

Necker Island

June 17-19. Abundant. Eggs to grown young seen resting on ledges of cliffs and on open slopes of island. June 20. About 4000 pairs nest here. The young wander about the rocky slopes, often tumbling head first over the ledges with no apparent harm. A good many are now in full first plumage but are loath to fly. June 29. Many young now are well grown.

French Frigate Shoals

June 26. 15 pairs on Skate Island, 15 pairs on Whale Island, with young well grown or on the wing.

Kaula Island

July 1. Abundant. One taken.

Johnston Island

July 10-17. About 25 on the main island and the same number on Sand Island. Now have young well grown or on the wing.

Wake Island

July 27-August 5. About 100 are found in two small groups one on the south and one on the north side of the main island. The birds are found on the rough coral of the outer beaches where they rest in the shade of bushes in company. They are not now breeding.

Sooty Tern *Sterna fuscata*

Laysan Island

April 8-13. A large colony circling east of lagoon. Several taken. May 2-3. Seen. May 4. Many fresh eggs in the colony at the *Sesuvium* patch. May 5. These birds are tame at their breeding sites and may be approached easily. I sat at the edge of the colony and watched them for several minutes this morning. Males seemed to pick the nesting area and protected it from encroachment. Any tern that showed a tendency to crowd in was driven out with open bill but others were disregarded. The battles seemed to be bloodless and I did not actually see them come to blows. When the female returned, the male strutted before her with quick mincing steps, wings hanging out from sides, neck extended and head rotated to one side. Copulation takes place on the ground with the female crouched prostrate and the male standing erect without a neck hold on her back. At every alarm among the terns, turnstones ran into seize their eggs. May 6. In the light of a flashlight these terns merely turn the back and make no attempt to fly. The clamor about their colonies is positively deafening and after a visit my ears ring as they do following a visit to some steel working factory. Destruction of eggs among them is heavy and I notice a steady diminution in the new colony in the *Sesuvium*. May 8-13. Larger numbers of these terns have joined the colonies in the past few days and the colony in the *Sesuvium* has grown steadily. May 13 I passed through the colony at the tobacco patch and found incubation begun with the females sitting closely. As I passed they called harshly and often permitted themselves to be touched before they left their eggs. These show an infinite variety in pattern and marking. With incubation begun, the colonies are much quieter than during the period of pairing and deposition. Pairs are often observed flying about in the air. Apparently selection of mates takes place in the air in pair[?] accounts for their flocking in the air before breeding.

Midway Island

April 23. A small colony located on Eastern Island. April 24. Fully 1500 circle day and night above Sand Island with endless chatter. By day their calls remind me of those of parrots while at night they suggest frogs.

Pearl and Hermes Reef

April 26. About 100 pairs on Southeast Island a few have eggs. April 27. 150 pairs on Seal Island, a few with eggs. April 29. A few noted passing at sea about 50 miles west of Laysan.

Lisiansky Island

May 16. A colony nesting in the grass tract. The majority now have eggs. The birds cover closely and often allowed me to step over them. May 18. Many. No young yet. May 19. About 250 pairs nesting here.

Gardiner Island

May 22. About 50 pairs on some of the higher flatter ledges with a few scattered about with the Gray-backed Terns. May 23. Seen at sea north of French Frigate Shoals.

Nihoa Island

May 24-26. Seen. June 11-16. About 6000 pairs bred from the lower rock cliffs clear to the higher summits. They gathered in small colonies on the lower slopes, the larger congregations being found on the highest slopes below the highest peak. An inner protected slope here that led steeply through a huge rock cleft was covered with the birds ranged just out of reach of one another. Distance between nest sites is determined by reaching distance and the males spar sharply when two alight too near. The majority of nests now contained fresh eggs, though on the higher slopes I found a few young in their curious first plumage that in some cases were awing. In early morning clouds of these and other terns came rushing down the slopes toward Adams Bay with great uproar and circled out in the air for a few minutes as they do in the mating season.

Necker Island

June 17-19. Abundant eggs to grown young noted. They have the same trick of rushing down the slopes in early morning in a screaming mass noted on Nihoa. June 20. About 15,000 pairs. Many are laying and others have young. June 29. Many young awing.

French Frigate Shoals

June 22-23. King Island. A few pass occasionally. June 26. Trig Island. 200 pairs. The birds here had eggs in most cases a good share of which were fresh. I collected a series and as before marvelled at their great diversity in form and color. As no two were alike, it might be supposed that difference in marking served to mark the nests of individual birds. To test this I exchanged eggs with two females with adjacent nests, one having a very white type egg and the other as markedly rufescent. The two returned to their respective nest sites and covered the strange eggs without the slightest hesitation. The same result was obtained when I exchanged a nearly plain egg for one heavily spotted one with elongate form for one nearly round, and one with bold dark markings for one very finely spotted. In all of these instances the females returned to their proper sites and adopted the strange egg. Finally I placed two eggs in one nest. The female returned and after considerable effort succeeded in covering both! Apparently site memory and not egg color serve to enable the owner to recognize its own home. I regretted that time did not

permit detailed observation to determine if there was any later reaction. When frightened from their nests thus at midday these tern before coming again to cover their eggs fly out and dip the breast until it is wet. This water is then transferred to the egg which it cools by evaporation thus counteracting the excessive sun heat. For further notes see journal. On Skate Island were 800 pairs. On Whale Island 125 pairs with eggs and young. June 28. 3500 pairs on Tern Island.

Kaula Island

July 1. Very abundant.

Johnston Island

July 10-17. Abundant. A few have eggs but the great majority have young on the wing or nearly ready to fly. Birds able to fly are still fed by the parents and rest with them at night, the colony at such times being spaced off as when there are eggs in it. The call of the young is high pitched. Those that I capture frequently regurgitate squid. One group that apparently have finished their breeding activities gather in a close flock on a stretch of open beach to sleep. The great majority are adults but with them are a few young. Partly grown young are pugnacious and bite each other savagely. The main impressions left on the mind by these large colonies are number of birds and noise. The clattering calls are uttered incessantly day and night. The birds are especially active and noisy during rains whether by day or night. The young when pursued by frigatebirds give up their fish without protest. About 2500 on Johnston Island, about 2000 on Sand Island.

Wake Island

July 27-August 5. A colony of about 300 birds found on the eastern end of Peale Island where they are now nesting. About one third have eggs, in part fresh and in part incubated. Their breeding season here is just beginning as females are laying or preparing to lay. They have chosen a site on bare sand in part shaded by *Tournefortia* trees. A small series of eggs taken July 30. The birds fly about over the entire island in pairs or little groups, either as part of a mating exhibition or in passing to fishing grounds. The pursuit of these terns by frigatebirds is spirited as the birds travel swiftly and dodge in and out. The robber follows relentlessly but is frequently foiled by some quick turn on the part of the pursued. This species suffered heavily at the hands of the Japanese poachers as the bones of thousands lie among the trees near the shack on Peale Island.

Brown Noddy *Anous stolidus*
(noddy)

Laysan Island

April 8-13. Bands of a hundred or more gathered in closed flocks on the sand beach near the water or rested on blocks of limestone. Not yet breeding. May 2. Flocks of 40 or 50 gathered on the beach in close array. One bunch seen near the lagoon gathered closely together on the sand. May 3. Noddies are spreading out to form colonies near the north end of the lagoon. Here the males rest a yard or so apart or flutter up with spread tail on rapidly moving wings in pursuit of females. One nest of a few sticks noted. Their note is a low harsh drawling "Kear-r-r". May 4-5. Seen. May 6. Like other terns these birds under a flashlight remain quiet and can be stroked without alarming them. May 13. Many of these terns are selecting nest sites and even beginning nests near the lagoon but I still see

flocks of 50 to 75 gathered at high tide mark on the sea shore. On the breeding grounds males droop their wings free from their sides and strut about like other terns. When approached they often elongate their necks in a curious manner.

Ocean Island

April 20. One taken.

Midway Island

April 23. A dozen pairs on Eastern Island. Two taken. Birds here have nearly grown young.

Pearl and Hermes Reef

April 26. About 30 pairs on Southeast Island. Young in some nests are nearly ready to fly. I noticed a number about dead with wounds on the head, probably the work of frigatebirds. April 27. Twenty pairs nesting on Grass Island and 30 pairs on Seal Island. Young well grown with a good many dead.

Lisiansky Island

May 16. Fairly common. Two nests seen that contained eggs. May 18. A bird taken at night while incubating an egg proved to be a male. Testes size of circle [oval 3 x 6 mm]. The birds are more nocturnal than other terns and I hear them calling continually through the night as they pass and repass. These birds often gather while the frigatebirds are harrying the shearwaters and apparently hang about to pick up discarded food. Large bands rest at tide mark on the beaches. May 19. About 500 pairs here. The birds are nesting mainly in scattered colonies in the inner basin and along the eastern shore. The nesting sites chosen are usually 12 to 30 feet apart in little depressions often at the mouths of old shearwater holes. Here the male rests or rises to circle gracefully through the air with his mate, the two wheeling and turning in close synchronism. The nest depressions are filled with a varied collection of small bones and feathers in lieu of other nesting material. Most are empty but a few contain one egg. Where nests are too near, the males strike at one another viciously. They stand about, frequently looking down as through at an egg, or strut with neck erect and bill pointed down and partly opened wings, walking with rapid steps before the female.

Gardiner Island

May 22. 125 pairs nested on the ledges in open colonies. Nests contained eggs varying from nearly plain to heavily spotted and equally variable in shape. The pyriform shape of most cliff-nesting birds does not hold in these, as their eggs varied from pyriform to oval. One or two nearly grown young noted.

Nihoa Island

May 24-26. Noted. June 11-16. About 2000 pairs nested here nearly half of them in a steeply sloping cleft between the two divisions of the highest peak. Small groups were scattered over the lower rock ledges above the sea while others ranged along the sides of the valleys. Most of them now had eggs, fresh or partly incubated. I collected a series. Nests were a flat platform of straws with a hollow for the single egg placed on the edge of

a rock or under the overhang of a little shelf. The birds are active at night and called continually as they passed over our camp.

Necker Island

June 17-19. Common nesting on open slopes. Eggs. June 20. About 3000 pairs. June 29. No change.

French Frigate Shoals

June 22-23. About 150 pairs on Round Island, 400 pairs on King Island. Some have young hatching now, a part of them dark and a part light in color. Parents threaten boobies and shearwaters with harsh notes when the latter intrude too near. June 24. 125 pairs with eggs on Little Gin Island. One newly hatched young taken. June 26. 150 pairs on Trig Island. 200 pairs on Skate Island. 300 pairs on Whale Island. June 27. 800 pairs on La Perouse Rock. June 28. 500 on Tern Island.

Kaula Island

July 1. 5000 pairs.

Johnston Island

July 10-17. Abundant. Breeding on sand beach, rock ledges and inland amid clumps of grass. About half have eggs, the rest young from newly hatched to grown. The newly hatched young are about evenly divided between light and dark. The nests of these birds are interesting. Some eggs are laid on bare sand or rock, others are deposited on a platform of grass with a slight central depression. Frequently the nest cavity contains ornaments in the form of entire shells, bits of larger shells, the calcareous opercula of cat's eye mollusks, bits of bone, a cranium or a mandible or even an odd-shaped piece of wood. It is always of interest to look over the collection and before now I have been guilty of filching some pretty shell from the lot. Mating activities are of interest. The male with neck erect and bill pointing down putters rapidly off across the sand perhaps in a semicircle to pause finally and look down as though at a nest. He then returns to his mate and the two rise and swing off in erratic circles with a synchronism of movement that holds them always 15 or 18 inches one above the other. About 800 on Sand Island, 1500 on Johnston Island. The black young number only about 10% of the white here at this island. [I cannot account for the discrepancy between this statement and that preceding, in which Wetmore states that the color phases were "evenly divided."]

Wake Island

July 27- August 5. The most abundant bird here, numbering at least 6000. The birds are now nesting and are distributed evenly over the entire atoll. Nests are masses of twigs a foot or so high and of equal diameter, sometimes smaller, placed in *Tournefortia* or *Pemphis* trees from three to fifteen feet from the ground. A few young are ready to fly, many are much smaller, and about one fourth of the nests contain eggs. A few nests are placed on large rocks, usually elevated where they are free from marauding crabs. As I pass through the trees the adults leave their nests with a rattle of wings on the branches and dash out to circle about with harsh calls. As I pass through the woods they are continually about me.

Black Noddy ***Anous minutus***
(Hawaiian Tern *Megalopterus* or *Micranous hawaiiensis*)

Laysan Island

April 8-13. Common. May 2. The young tern in the bird room has grown surprisingly since my departure. It was apparently about a week old when we arrived. The nest was placed on a shelf at the darkest end of the room. The parents were not disturbed by our rude possession of the place but when we closed one window to keep out sand they left the young bird for two days, apparently because they had been passing in and out through that opening. I fed the youngster on bird meat and made a small opening through which the adults finally returned. Now the parents have learned to pass though another window, or the door, and go and come while we are at work. Their arrival is announced by their harsh clattering call that has the pitch and sound of a stick drawn across palings or the wooden cog wheel and ratchet toy of children. They are very tame and peck at my hand when I touch them. As they alight the youngster begins a low sibilant whistle while it crouches with lowered head. It begins then to nibble at bill of the parent who swallows two or three times and then opens the bill and raises a small fish. The youngster seizes this from the throat of the parent. After a minute or so the process is repeated. One seen making a nest with bits of green and red algae brought up from the beach. Some nest in the ironwood and hau trees beneath and within a few feet of the Red-footed Boobies and there is a colony on the corrugated iron roof of our old shed. Others breed on suitable sites on rock ledges along the beach. May 3. Seen. May 4. The young bird in the bird room, in begging for food, assumes an attitude in which the breast rests prostrate on the nest while the posterior end of the body stands erect. May 7. It stands or walks about flapping his wings trying the muscles. It was a day or two old when we arrived. May 13. It is flying about the room now and is about ready to venture out. May 13. Nests in rock piles along shore in some cases contain fresh eggs. I took pictures of birds at incomplete nests today at a distance of three feet. The birds nest in little colonies. Some build in the coconut trees at the house.

Ocean Island

April 17-19. Fairly common. April 20-22. Single birds or twos or three beat along the beaches just above the wash of the waves occasionally darting down at small fishes.

Midway Island

April 23. A few recorded on Eastern Island. April 24. Seen on Sand Island.

Pearl and Hermes Reef

April 26. About 50 pairs nest on Southeast Island where they place their nests on low clumps of grass or on the ground. I collected a fresh-laid egg and saw young nearly ready to fly. I picked up one or two adults in my hand. The adults are feeding their young on *Janthina*, a small mollusk with a thin, friable, purple shell, a species that floats on the open sea. The fragments of shell are cast as pellets that lie about the nests. Pellets and some entire shells collected. Identified by Thaanum. (*Janthina bifida* Nuttall det. J. P. E. Morrison.) [Note added later; Morrison was a malacologist at the Smithsonian.] April 27. Twenty pairs on Grass Island, 20 pairs on Seal Island with well grown young. April 28. Some young about ready to fly on Southeast Island. Considerable mortality among them.

Lisiansky Island

May 16. Seen. May 18. Common but no nests seen. Found in flocks on beaches with other noddies. May 19. About 1000 resting on beaches. No nests seen here.

Gardiner Island

May 22. About 10 pairs with nests. About 200 other birds rested in close flocks on the rocks near the water.

Nihoa Island

May 24-26. Seen. June 11-16. Though this tern was seen in small numbers as noted above on the rock shelves below the high cliffs at the western side of the island, none were recorded in along Adams Bay during my stay in June.

Necker Island

June 17-19. About 100 pairs nesting in cleft on the cliffs.

French Frigate Shoals

King Island. June 22. One taken from a flock of a dozen that passed. June 25. See journal. June 27. 150 pairs on La Perouse Rock.

Kaula Island

July 1. 1000 pairs.

Johnston Island

July 19. One reported by C. Grant. I thought I heard one calling on first arrival here but was not certain.

Wake Island

July 27 to August 5. About 200 nest in the *Tournefortia* trees near the beach, scattered among the noddies. Nests now contain young. Adults fly about my head with their harsh rattling calls. Not found far inland. Feet and tarsi vary from blackish brown to dark orange.

Blue-gray Noddy *Procelsterna cerulea*
(Necker Island Tern *Procelsterna saxatilis*)

Gardiner Island

May 22. At daybreak this morning two or three of these little terns came about ship where I was delighted to see them. On first landing I looked eagerly for their small forms among the many birds circling about for the first fifteen minutes without results. In fact I had begun to doubt my early morning identification until I found two fluttering about a little rock ledge on the eastern face of the island. These two were soon in hand and I was admiring their quiet coloration. The large size of the feet and strength of the tarsi in

comparison to their size was in particular notable. Later I found three about another rock ledge and shot one and in all saw about a dozen.

Nihoa Island

May 24-26. About 100 noted on the rock cliffs at the western side of the island. The birds were associated in pairs that congregated in one spot to the number of twelve or fifteen couples and elsewhere were scattered among the White Terns. None of the ledges that they frequented were more than 200 feet from the water. Their flight was accomplished by short fluttering strokes of the wings entirely different from those of other terns and on alighting they fluttered the wings and tail several times to settle the feathers, in a manner peculiar to themselves alone. It was interesting to note that at times as they passed over the waves they dropped the feet and pattered along like petrels for a few strokes, which explained the apparent over development of the lower members.

June 11-16. Common. Probably 800 pairs inhabit the island. The birds were scattered all along the rock ledges of the cliffs that bordered Adams Bay where they nested in little hollows and holes of small size that still gave these graceful little terns abundant room. The single egg was laid on the bare rock. Only four eggs were seen and of these it was only possible to blow one that was addled. The others contained embryos nearly ready to hatch. I saw a few young newly hatched, some slightly older and numbers on the wing. Adults and young were molting and were not in good plumage. One young bird, nearly grown, occupied a hole under an overhanging ledge where we skinned our specimens. When approached it retreated out of sight but at other times rested at the entrance to the hole erect and dignified. When the parent came in its attitude changed at once and it crouched with lowered head uttering a low sibilant whistle like the call of a squab while it pecked constantly at the feet and tarsi of the adult. After a minute or two the parent regurgitated a small fish which the youngster seized from the rock and swallowed. These terns ranged along small rock ledges in the valleys to an altitude of 500 feet but were more common on the cliffs fronting the sea. They had one very pretty habit of dropping the feet and then descending toward me in a series of short graceful loops with wings held stiffly at a slight elevation above the back. After alighting, the wings were fluttered against the sides to fold them in place. Their call was a low, wailing "Krah-h-h-h", a mournful drawn out sound. They were quite graceful little creatures that rested quietly on the rock ledges or sailed about among the other terns. A hundred or more sometimes gathered in little caves sheltered from the intense heat of the midday sun.

Necker Island

June 17-19. Common. Nesting season here farther advanced as all young seem to be awing. This species frequents little caves and overhanging ledges and does not come out on the open high slopes. Many seen now to spend the day at sea and return to roost at night. At nightfall they are common about camp but few are seen during the day. June 20. About 400 pairs.

French Frigate Shoals

June 27. La Perouse Rock. About 20 seen. 3 taken.

Kaula Island

July 1. About 25 seen. One taken.

Johnston Island

July 13. Three found among clumps of grass below a low hill. Two taken.

White Tern *Gygis alba*
(Love Tern, Love Bird)

Laysan Island

April 8-13. Common. On our arrival several had eggs about the old shacks but one by one these were eaten by the finches until none remained. One bird that had laid on a two-by-four in the frame of a shanty that we use as kitchen continued to incubate calmly, in spite of our coming and going a few feet below, but finally lost her egg. One or two had newly hatched young that clung to my fingers tenaciously with their long toes, showing no fear of falling. One bird at the blowhole had a youngster perched on a little rock ledge in the shade, while three feet below minnows suitable for food swam back and forth and were available for the mother at need.

April 29-May 12. A heavy surf during my absence swept the limestone ledges at the blowhole and destroyed all eggs and young of this species there. The adults nested again at once and further eggs were deposited. These were placed on tiny ledges in the limestone rock, sometimes exposed and sometimes well in under overhanging shelves. Occasionally eggs were laid in little depressions in the tops of boulders. Many times their positions seemed precarious in the extreme. The parent in incubating sat partly erect behind the egg and threw the feathers of the abdomen down over it to cover it. The location of this colony seemed very unsafe and I collected a part of the eggs. A storm on May 11 washed away the remainder.

In addition to the colony at the blowhole a few were found about the old guano piles, the southeastern rock ledges, at the *Sesuvium* along the beach to the southwest and about the old buildings. They exhibit much curiosity and come out to hover in the air a foot to six feet from one's head, giving opportunity to observe their pure coloring at its best. The dark markings about the eye give that liquid orb an appearance of size and depth that is deceptive. Though they rest at night, they appear to be able to see well in the dark and often fly about long after sunset. Their notes do not correspond with their coloration, as they consist of a series of low froglike grunts uttered in a peculiar tone wholly unlike any other bird notes known to me. They are solicitous for eggs or young and when the latter have been destroyed in any way seem hardly able to realize the fact as for a day or two they may come peering about to bring it food.

[An evanescent contribution of this species and the TANAGER Expedition to zoology, was the description of a new family, genus, and species of fish, *Gregoryina gygis*, Gregoryindae (Fowler and Ball, 1924:271), based on single specimen "obtained on Laysan Island, where it was brought to a nest by a white tern (*Gygis alba kittlitzi*), May 12, 1923," and preserved by Ball. The genus was dedicated to H. E. Gregory, director of the Bishop Museum, and the species was dedicated to the collector. Tinker (1978:237) made the jocular observation that this "is an example of the extreme depravity to which scientists will descend to obtain a new species, namely taking food from a little bird." The story has an even unhappier ending, however, for it was later determined that *Gregoryina gygis* is a late postlarval stage of *Cheilodactylus vittatus* (Cheilodactylidae) and all the names based on the baby tern's dinner have disappeared into synonymy (Randall, 1983).]

Midway Island

April 22-24. Fairly common on both Eastern and Sand Island. One bird had laid in a large *Scaevola* limb and had a youngster perched in the branches. Another had deposited an egg on a bit of drift, part of a log near the beach. Two adults taken on Eastern Island.

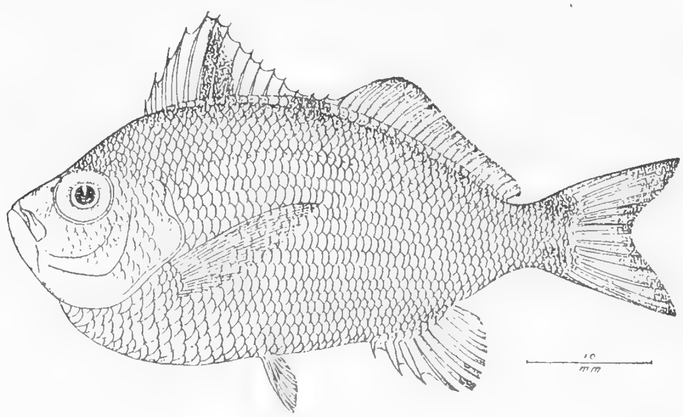

Figure 49. [Holotype of *Gregoryina gygis* = *Cheilodactylus vittatus* (From Fowler, 1928:224).]

Pearl and Hermes Reef

April 26. One seen on Southeast Island.

Lisiansky Island

May 15. One seen. May 17. Two hovered over my tent this evening. Have not found the birds resting on the rocks on this island however. May 21. Seen occasionally at sea today between Maro and Dowsett and Gardiner Island.

Gardiner Island

May 22. Common. In pairs nesting on the steep rock surfaces. About 150-200 pairs. Two taken were mated and I found developing eggs in the female. May 23. Noted occasionally at sea north of French Frigate Shoals.

Nihoa Island

May 24-26. The White Tern is abundant on the huge cliff that forms the western side of Nihoa. During the two days here I have had some opportunity to observe them. Birds were scattered in pairs over the greater part of the huge rock surface, occasional dots of white marking breeding sites at elevations of 700 or 800 feet below Millers Peak. Comparatively few ranged above 500 feet and the greater part clustered in the colony and some scattered groups between 20 and 250 feet from the sea. Even these had their eggs and young at dizzy heights above the ocean. In the colony mentioned above were clustered perhaps 150 pairs in an area 200 by 100 feet where at a distance the rock seemed yellow and of a different nature than the surrounding stone. On close approach, however, I found the yellow appearance due to guano deposited by the birds over the edges of their nest ledges. For thirty to forty feet above the water the ledges were washed clean, though scattered pairs of birds were nesting. Evidently surf reached that high. There was much

activity among these terns as they fluttered out and back continually at intervals. A pair sailed out in a great circle with set wings each synchronizing its movements with the other so that they maintained a set distance of 10 or twelve inches apart. Occasionally three individuals joined in these mating flights. A few came out to investigate the ship and more to hover with their curious little grunting cries over the surfboat, but the main colony went on undisturbed in their usual activities in spite of loud shouts intended to frighten them. I have not seen the frigatebird molesting these terns. June 11-16. Abundant on the high cliffs of the west, north, and east faces of the island but not seen on the slopes that lead down into Adams Bay, or the ledges that front. Those collected were taken on shelves at the summits of the high outer cliffs. About 4000 pairs was my estimate for the entire island. Some were just beginning to breed, others seemed to have young.

Necker Island

June 17-19. Common. Eggs and young. June 20. About 400 pairs. June 29. No change.

French Frigate Shoals

June 22-23. King Island. Pass occasionally from the high rock. June 27. La Perouse Rock. 300 pairs. Occasional pairs or little flocks pass the other islands en route to some feeding ground at sea.

Kaula Island

July 1. About 100 pairs.

Johnston Island

July 10-17. About 20 on the low rock ledges of the main island divided in two small colonies, one on the east and one on the north. Have eggs or newly hatched young. Bill is bright blue at base in life, shading to black at tip. About 40 on Johnston Island.

Wake Island

July 27 to August 5. Abundant. Fully 2500 on the three islands. The birds are found in little groups of two or three pairs among the *Tournefortia* trees, where they lay their eggs on little depressions or scars on limbs one and one half to two and one half inches in diameter, from two to fifteen feet from the ground. Some eggs are fresh, other parents have nearly grown young. Though the Love Birds come and hover overhead, as elsewhere they are wild and seldom approach within 20 feet. In addition to their froglike grunts they sometimes utter a high pitched squeaky whistle ee-ei-ee-ei [not clear]. The skin in this species is black and the feathers loosely attached.

Nihoa Millerbird *Acrocephalus kingi*
(*Tatare*)

Nihoa Island

June 11-16. Possibly 100 of these little birds are found on Nihoa. They inhabit the heaviest growths of *Chenopodium* in the bottoms of the gulches, or on the slopes above, but range in small numbers to the tops of the highest hills. They moved leisurely and kept

well hidden, so that it was difficult to see them especially since they kept in the densest cover near the ground. Their curiosity was often attracted by a squeak when they hopped up into the outer limbs to peer about. As they peered out they suggest small vireos and their call was similar to that of a bird of that group. Adults all lacked tails and were molting otherwise. Young were fully grown and were molting into first full plumage.

[The Nihoa Millerbird was the ornithological highlight of the TANAGER expedition, being the only new form of bird discovered. It was originally described by Wetmore (1924) as a full species *Conopoderas kingi* in honor of the commander of the TANAGER. *Conopoderas* and *Tatare* are names formerly applied to the Pacific warblers that were later considered to belong in the widespread Old World genus *Acrocephalus*. The Nihoa Millerbird is now usually considered to be a subspecies of the extinct Laysan Millerbird *Acrocephalus familiaris*, though the two are quite distinct in plumage and morphology. Wetmore had occasion to re-examine this question nearly forty years after describing *A. kingi*, when he was asked by the Fish and Wildlife service to provide information on the Nihoa Millerbird. In a memorandum to John W. Aldrich dated 15 August 1962 he wrote: "Superficially the bird of Laysan (now extinct) and that of Nihoa are similar in general appearance, which has led to the supposition indicated of subspecific relationship. It appears evident that the two probably have had a common ancestry. But on study I find that in details of structure of wing, bill, and feet, the two differ to such a degree that I still regard them as two distinct species." I concur.]

Laysan Apapane *Himatione sanguinea freethii*

Laysan Island

April 8-30, 1923. Three seen at intervals about piles of rock at the southern end of the lagoon. May 13. These birds have not been seen since the heavy storm after the twentieth of April and it is supposed that they have perished. I have visited their haunt on a number of occasions without finding them.

Common Canary *Serinus canarius*

Midway Island

April 22-24. On Sand Island the canary is abundant in the trees and shrubbery about the buildings but does not occur on the wilder part of the island. In early morning their songs, with those of the Laysan Finches, formed a pleasing morning chorus. The birds are common in the lawns and shrubbery and also range out through the ironwoods at a distance. All seen are yellow to very pale yellow. Several young just from the nest noted. The canary seems very small and weak beside the aggressive Laysan Finch. I am struck especially with the small size of the head in *Serinus*. [See W. A. Bryan (1912) concerning the introduction of this species to Midway.]

Laysan Finch *Telespiza cantans*
(*Telespyza cantans*)

Laysan Island

April 8-13, 1923. On first landing the island seemed such a desert that I had no hope that the finch had survived but in a few minutes one came hopping about the porch of one of the shacks, another one or two came out on fronds of the coconuts, and one was

seen in an out building. Soon six or seven were hopping about us. Within half an hour the little birds had cleaned up the *Megalopterus* and *Gygis* eggs about the shacks, as they broke and ate the eggs instantly when they were deserted by the owners. Following this they increased in numbers about the buildings until 15 or 20 were about and I found them about the *Sesuvium* patch and around rock piles, all, however, on the inner protected rim of the island. At the shacks they flew and hopped in and out with the utmost familiarity or came into our tents. They kept barely out of reach but showed no fear at all. They were greatly taken with water that dripped from the water breakers so we put out little pans of water for them which proved a great attraction. A female began a nest inside one of the windows against a board and carried in bits of excelsior. They are into everything and discovered an open case of eggs in the store room in fifteen minutes and had eaten four or five.

April 30. Four females taken on Midway released here as the authorities permit importation of male birds here only. [This refers to the fact that Wetmore had obtained permission to bring only male birds to the main Hawaiian Islands, which was a precaution against unintentional introduction. Later the authorities considered that even this might be ill-advised as perhpas there might be females among the males. The precaution was unnecessary because the fossil record now shows that the Laysan Finch once inhabited the main Hawaiian Islands (James and Olson, 1991).]

May 1-3. The birds came familiarly about the cabin as before. One or two females seem prepared to build and have started several nests but males pay little attention to them. Two or three came about and drank small quantities of salt water dripping from my bathing suit as it hung from a post. May 4. Come in familiarly to drink at water pail. May 5. These little birds are found all through the little piles of rocks near the lagoon and are building nests in the crevices in the rocks. They are extremely tame. It is not unusual to have one hop up on my foot as I write or work. At night they roost on beams and window ledges and in early morning hop familiarly about our beds. May 7. One comes at evening and sings from a rafter during our supper hour repeating his song steadily for fifteen or twenty minutes. They come frequently to test the salt water dripping from a wet bathing suit and one even tried to drink kerosene from a cup.

May 8. One has an egg in the nest at the house. May 9 a second egg laid. The female sits closely, perhaps to prevent pillage by her friends. Once when she left the nest herself she partly covered the eggs with some bits of excelsior and string. May 10. A third egg laid. May 12. Set collected as it is apparently complete. Tonight I counted 20 at roost in various corners of the storeroom mated pairs rested within three or four inches of one another. Others were scattered about at random. The song of this species is varied, sweet and pleasing. At times it is suggestive of a House Wren [*Troglodytes aedon*] or thrasher [*Toxostoma* sp.]. The birds sing a great deal especially during morning and evening. Several pairs are busied with nest building.

Midway Island

April 22-24. ~~Very~~ abundant. On Eastern Island the birds were spread out through the brush and came out in the little central openings where they were protected from the wind to feed. On Sand Island they were all about the houses as familiarly as on Laysan. Little parties came to feed on broken corn (chick feed) on the verandah in front of my room and in early morning the pleasing song of the males made a beautiful chorus. A considerable number were captured alive and taken aboard ship where they began to feed and seemed at once reconciled to confinement.

Nihoa Finch *Telespiza ultima*
(*Telespyza ultima*)

Nihoa Island

June 11-16, 1923. There are fully 800 of these finches on the island. At the present time they have finished breeding and adults are in molt. The young birds in their streaked plumage are everywhere in evidence but adults are shy and more frequently remain hidden. The finches range to the summits of the highest peaks but are most abundant in the lower stretches of the gulches especially where tiny pools of water are found in depressions in the rock floor of the valleys. Dozens congregate here in the *Chenopodium* bushes where they rest quietly or clamber about, their total number unsuspected until one tramps through the coverts. They are still in little family parties, some of them only recently from the nest. Often fifty were found about one water hole. Adults were silent save for chirping notes, but young frequently uttered a low twittering song that, while not equal to the sounds produced by the adult Laysan bird, was very pleasing. These little finches were tame and came without fear about our camp peering curiously at strange paraphernalia and pecking and pulling at ropes and strings. Adults and young relished eggs of other birds and literally thousands of tern, shearwater and petrel eggs, with the sides cut open by the finches lay about. Their flight was strong and on the ground they hopped. I found one nest that can have belonged to no other species, in a slight cavity under a ledge at the summit of a cliff 500 feet high. The structure was a cup of fine grasses and stems of weeds. The rim and the rock about were foul with the excrement of the young, the filthy condition reminding one strongly of the nest of the House Finch. The bill in this species is brown, paler below. The small size of the eye cavity suggests the condition found in goldfinches and siskins [*Carduelis* spp.].

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AN ANNOTATED BIBLIOGRAPHY OF LAYSAN ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

BY

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AN ANNOTATED BIBLIOGRAPHY OF LAYSAN ISLAND, NORTHWESTERN HAWAIIAN ISLANDS

BY

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INTRODUCTION

The nineteenth century was a period of great discovery for the terrestria biota of the Northwestern Hawaiian Islands, and especially Laysan Island. More comprehensive surveys were undertaken early in the 20th century, after Theodore Roosevelt established the Hawaiian Islands Bird Reservation in 1909. During the 1960s, studies by the Smithsonian Pacific Ocean Biological Survey Program vastly increased our knowledge of these islands and included among them a comprehensive monograph on the natural history of Laysan Island by C. A. Ely and R. B. Clapp (1973).

Beginning in the mid-1970s, Laysan and its sister islands received further attention with the expanded study of endangered vertebrates by the U. S. Fish and Wildlife Service (which administers these islands), and with Hawaii's growing interest in the fishery resources of the area as reflected in studies by the National Marine Fisheries Service. Two symposium volumes (Grigg and Pfund 1980; Grigg and Tanouye 1984) and many reports on endangered vertebrates followed such as the series of papers on the Hawaiian Monk Seal (*Monachus schauinslandi*) authored by the Johnsons, on sea turtles by Balazs and his colleagues on sea turtles, and on the Laysan Finch (*Telespyza cantans*) by Conant and Morin. These and other studies and incidental observations have provided much new information on the biota of Laysan and the other Northwestern Hawaiian Islands. Indeed, almost as many published and unpublished reports on Laysan Island have come out in the last 20 years as in the preceeding century.

Because this material is scattered over hundreds of professional journals and other periodicals, we decided to prepare a bibliography to make easier the task of those intending to conduct research on Laysan in the future. As we worked on this bibliography it occurred to us that it would be worthwhile to include the earlier bibliography in Ely and Clapp so as to have a single complete source of information on the literature of this atoll.

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The 1973 bibliography was by no means intended to be exhaustive but was to be an index to the primary papers dealing with various aspects of the fauna and flora. Often the latest paper on a subject was used rather than list the three or four previous papers on which it may have been largely based. For the convenience of the reader, this bibliography includes many of the earlier papers not included in the Laysan account, and corrects others that were incorrect in or inadvertently omitted from Ely and Clapp (1973). We also include a number of anonymous newspaper articles for which we know the date of publication but not the page numbers. Many of these would be useful in constructing a detailed history of Laysan and the Northwestern Hawaiian Islands and are included to aid in such studies.

Our current bibliography lists 1076 titles referring to Laysan, not including several more that were excluded for being too peripheral or which only duplicated information included in other titles included herein. The original bibliography in Ely and Clapp contained 286 titles, with many of them literature specific to organisms or general subjects and not necessarily including Laysan. This drastic increase over the last 22 years once again emphasizes the much expanded role of research in the Northwestern Hawaiian Islands.

Titles are sometimes supplied in brackets when the original material lacked them. Many, but not all, titles are annotated; titles lacking annotations are usually those whose titles very adequately indicate the paper's contents. We have usually only briefly annotated published papers or books that are easily accessible and have given more extensive annotations of manuscript material that is often found at only one or two sites and which may be difficult or impossible to consult without considerable effort. Our annotations are limited for publications with only minimal information on Laysan Island.

Scientific names are reported as they appear in original reports, but amended names are often referred back to earlier papers. We have not included some popular works that only rehash well-known information on Laysan, nor have we included some technical papers that only secondarily refer to Laysan and which provide no new information.

During the Smithsonian Pacific Ocean Biological Survey Program (hereafter POBSP), 1962-1970, a very extensive literature survey was conducted for references to the central Pacific Islands covered by this project (those in an area from 30° N to 10° S and from 150° W to 180° W (Humphrey 1965)). Translations were also made of a considerable number of papers in foreign languages, particularly the reports stemming from Schauinsland's Expedition to Laysan in 1896. In some instances, these files do not include the complete publication, particularly when the material appears in a lengthy book; in such instances, only those pages specifically pertaining to the islands were copied.

In addition many hundreds of man-hours were spent looking for, taking notes on, and copying unpublished sources of information, principally in the files of the U. S. Fish and Wildlife Service, the Hawaii Division of Fish and Game, the Bernice P. Bishop Museum and other sources in Honolulu, HI, and in various Record Groups in the U. S. National Archives in Washington, DC. The results of this search, something over 1850 titles, are now housed in the Smithsonian Natural History building in Room 434. Because these files provide a unique source of information on Laysan and other Northwestern Hawaiian Islands we have decided to include the file number for each of the titles occurring there and appearing in this bibliography. Such files are indicated by the entry [POBSP - followed by the file folder number.]

Originals of unpublished POBSP reports are held in the U. S. National Museum Archives in Washington D.C., and copies of most of these are in a series of numbered blue bound volumes presently kept in the Smithsonian Bird Division library. Such reports are indicated by entries such as POBSP BB (blue book) followed by the number of the volume and/or by the SI Archives, Series, Box, and Folder numbers, e.g. SIA 2, 17, 8. [All are in Record Group 245]

Because the authors of this bibliography are principally vertebrate ecologists or ornithologists, we cannot be certain, indeed doubt, that the listing of papers for the flora or invertebrates is absolutely complete. We do feel, however, that the bibliography, listing as it does, so many unpublished and obscure sources of information, should be highly helpful to future researchers.

The reader should note that much of the manuscript material, other than that in the U. S. National Archives, may not be in the public domain and may not be available on request to some of the holding facilities.

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Biological Survey, Smithsonian Institution, Washington, DC), Sheila Conant, E. Alison Kay, Ernest Reese (University of Hawaii, Honolulu, HI), Andy Engilis (Ducks Unlimited, Sacramento, CA), Elizabeth Flint, Jeffrey S. Marks, D. Kenneth McDermond, Mark Webber, Ronald L. Walker (U. S. Fish and Wildlife Service, Honolulu, HI), Derral Herbst (U.S. Army Corps of Engineers, Honolulu, HI), Karl W. Kenyon (Seattle, WA), Cameron B. Kepler (National Biological Survey, Athens, GA), Eugene Kridler (Sequim, Washington), Michel Louette (Museum for Middle Africa, Tervuren, Belgium), James E. Maragos (East-West Center, University of Hawaii, Honolulu, HI), Ann. P. Marshall (Division of Fish and Wildlife, Department of Lands and Natural Resources, Commonwealth of the Northern Marianas), Marie P. Morin (Hawaii Volcanoes National Park, Hawaii, HI), Audrey L. Newman (The Nature Conservancy, Honolulu, HI), Dan Nicolson (Dep. Botany, Smithsonian Institution, Washington DC), Stephen Ralston (U. S. Dep. Commerce, NOAA, Tiburon, CA), Richard L. Pyle, Robert L. Pyle, Lucius Eldredge, John E. Randall (B. P. Bishop Museum, Honolulu, HI).

CITATIONS

Abbott, I. A. 1989. Marine algae of the Northwest Hawaiian Islands. Pacific Sci. 43(3): 223-233. [Records for all the Northwestern Hawaiian Islands with some hitherto unreported from Laysan.]

Abbott, R. T. 1968. The Helmet Shells of the World (Cassidae). Part 1. Indo-Pacific Mollusca 2(9): 15-202. [Records *Casmaria erinaceus kalosmodix* (Melville, 1883)(p. 193) from Kure Atoll, Midway Atoll, Laysan, Lisianski, and Pearl and Hermes Reef in the Northwestern Hawaiian Islands.]

Abood, H. 1959. Rare Laysan Teal thrive on tiny isle. Honolulu Star-Bulletin, May 20, 1959: D-11. [Reports [G. D.] Butler [Jr.], [H.] Caspers and Bill Smithe's [sic = W. R. Smythe] 3 days on Laysan; estimate of 500-600 ducks mentioned]

Adams, J., and H. Nevins. 1994ms. Trip Report: Laysan Island, 8 June - 23 October 1994. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, HI. 31 pp. (and 11 unnumbered pp. of maps, figure, and data). [Information on *Cenchrus* control and Laysan Duck (*Anas laysanensis*) counts, an estimate of the Laysan Finch (*Telespyza cantans*) population, censuses of the three species of boobies, the Great Frigatebird (*Fregata minor*), Red-tailed Tropicbird (*Phaethon rubricauda*), Black Noddy (*Anous minutus*), and White Tern (*Gygis alba*); notes on other species and vagrants but with little information on the latter; data on plants, seals, turtles, invertebrates, weather and maps of breeding areas of Sooty Terns (*Sterna fuscata*) and White Terns.]

Agassiz, A., and H. L. Clark. 1907. Preliminary report on the Echini collected, in 1902, among the Hawaiian Islands, by the U. S. Fish Commission Steamer "Albatross", in charge of Commander Chauncey Thomas, U.S.N., Commanding. Bull. Mus. Comp.

Zool. 50(8): 231-259. [Reports 8 echinoderms collected at and near Laysan; one, *Clypeaster lytopetalus*, is described as a new species.] [POBSP 1577]

Agassiz, A. and H. L. Clark. 1907-1912. Hawaiian and other Pacific Echini. Mus. Comp. Zool. Harvard, Mem. 34: vii and 383 pp. [Further report on the echinoderms collected by the Albatross Expedition] [POBSP 1562]

Aiman, E. 1944. American acquisition and development of minor Pacific islands. M.A. Thesis, Univ. Chicago. [Historical summary of early visits to Laysan and other Northwestern Hawaiian Islands (pp. 11-12). Pp. 22-24 deal specifically with Laysan.] [part only in POPSP 1745]

Alcorn, D. J. 1984. The Hawaiian Monk Seal on Laysan Island: 1982. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-42 iii + 37 pp. [Studies conducted 15 March-30 June and 10 July provide data on populations, reproduction, factors affecting survival. Counts ranged from 66 to 119 and averaged 90.]

Alcorn, D. J., and E. K. Buelna. 1989. The Hawaiian Monk Seal on Laysan Island 1983. NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-124. v + 46 pp.

Alcorn, D. J., and R. Henderson. 1984. Resumption of nursing in weaned Hawaiian Monk Seal pups. 'Elepaio 45(2): 11-12. [One observation each on Lisianski and Laysan islands.]

Alcorn, D. J., and A. K. H. Kam, 1986. Fatal shark attack on a Hawaiian Monk Seal (*Monachus schauinslandi*). Mar. Mamm. Sci. 2(4): 313-315. [By a tiger shark (*Galeocerdo cuvier*) at Laysan 28 May 1982]

Alcorn, D. J., and R. L. Westlake. 1993. The Hawaiian Monk Seal on Laysan Island: 1986. U.S. Dep. Comm., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS--SWFC-191. iii + 25 pp.

Alfken, J. D. 1903. Beitrag zur Insektenfauna der Hawaiischen und Neuseeländischen Inseln. (Ergebnisse einer Reise nach dem Pacific, Schauinsland, 1896-97). Zool. Jahrb., Syst. 19: 561-628. [Reports 17 species of insects from Laysan from collections by Schauinsland] [POBSP 1586]

Allen, G. M. 1942. Extinct and vanishing mammals of the Western Hemisphere. Am. Committee for Internatl. Wild Life Protection, Lancaster, PA. 620 pp. [Laysan mentioned (pp. 456-457) in account of Hawaiian Monk Seal but entirely derivative] [POBSP 384]

Allen, J. A. 1918. The Laysan Seal. Amer. Mus. J. 18(5): 399-400. [Comments on Bailey collection of seal at Laysan; largely derivative.].

Altonn, H. 1961. Devastated atoll now teaming with birds, seals. Honolulu Star-Bulletin, September 20, 1961: A3-1. [Report about the Coolidge Expedition to Laysan in September 1961]

Altonn, H. 1970. Two convicted of trespassing on island refuge. Honolulu Star-Bulletin, June 3, 1970: A-11. [Two of four men that went ashore in April 1970 to salvage fishing long-line and glass floats from wreck of Japanese fishing boat.]

Altonn, H. 1978. Scientists studying monk seal deaths. 'Elepaio, 39(1): 11. [Excerpted from an article by Helen Altonn, Honolulu Star-Bulletin, May 18, 1978].

Amerson, A. B., Jr. 1964ms. Northwest Hawaiian Islands trip report, March 1964. Leeward Survey No. 3. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 20 pp. [Two page table 4 lists 26 species of birds seen with population estimates and some information on breeding status.] [POBSP BB 8 (pt)/ SIA 37, 163, 9]

Amerson, A. B., Jr. 1966ms a. POBSP ectoparasite survey for Laysan Island. POBSP unpublished ms., 16 May 1966, Smithsonian Institution, Washington, DC. 6 pp. [Summary of collections for visits from February 1963 through August 1965] [POBSP BB 8]

Amerson, A. B., Jr. 1966ms b. Laysan ectoparasite addendum. POBSP unpublished ms., 16 May 1966, Smithsonian Institution, Washington, DC. 1 p. [Summary of collections for visits in June 1966] [POBSP BB 8]

Amerson, A. B., Jr. 1966. *Ornithodoros capensis* (Acarina: Argasidae) infesting Sooty Tern (*Sterna fuscata*) nasal cavities. J. Parasit. 52(6): 1220-1221. [Including specimens from Laysan collected 8 August 1965] [POBSP 1653]

Amerson, A. B., Jr. 1968. Tick distribution in the central Pacific as influenced by seabird movement. J. Med. Entomol. 5(3): 332-339. [Report on collections made by the POBSP.] [POBSP 1658]

Amerson, A. B.. Jr., and K. C. Emerson. 1971. Records of Mallophaga from Pacific birds. Atoll Res. Bull. 146. 30 pp. [Lists, but without specific dates, records from birds on Kure, Laysan, Midway, French Frigate Shoals, Pearl and Hermes Reef, Wake, and Johnston Atoll among others. Most of the North Pacific records are from Kure Atoll.]

Amerman, K. E. 1964ms. Laysan Island, 16-20 September 1964. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 8 pp. [Brief notes, largely on 23 species of birds and results of Hawaiian Monk Seal census conducted by the USFWS 19 September] [POBSP BB 8/ SIA 37, 163, 10]

Anonymous. 1905. An island schooner's bunch of disasters. Paradise of the Pacific 18(9): 17-18. [Ship *Charles Levi Woodbury* hauling fertilizer from Laysan 13 July 1905 met with bad seas and had to return to Laysan 9 August, the repaired ship reaching Oahu 3 September. During the storm 150 Laysan Finches that Max Schlemmer had intended to "dispose of" were swept overboard and drowned.] [POBSP 346]

Anonymous. 1908. Albatross on Laysan Island. Paradise of the Pacific 11: 15. [Very general account of albatross with species not indicated]

Anonymous. 1910a. Notes and news. Auk 27(2): 243-244. [On pp. 243-244 quotes from the Army and Navy Register, February 10, 1910. The Commander of the Thetis reports about some Japanese caught at Laysan taking in August 1909 alone 128.100 wings in 70 bales weighing 1 ton.]

Anonymous. 1910b. Government claims skins. Pacific Commercial Advertiser, Honolulu, February 15, 1910. [U. S. District Attorney Breckons claimed plumage seized from Japanese because the plumage was taken from what is American territory. Partial indictment expected this morning of 23 captured Japanese and "Max Schlemmer who is accused of being their American representative, if not their actual head."] [POBSP 1550]

Anonymous. 1910c. Embezzler goes to settlement -- Japanese Bird Poachers are given one week in which to plead. Pacific Commercial Advertiser, Honolulu, February 22, 1910. [23 poachers captured on Laysan] [POBSP 1550]

Anonymous. 1910d. Judge sustains Max Schlemmer. Pacific Commercial Advertiser, Honolulu, April 21, 1910. [Schlemmer excused from two indictments on technical grounds.] [POBSP 1550]

Anonymous. 1910e. Max Schlemmer again indicted. Pacific Commercial Advertiser, Honolulu, July 2, 1910. [Charged with bringing aliens into country unlawfully] [POBSP 1550]

Anonymous. 1913. Notes and exhibitions. Proc. Haw. Entomol. Soc. 3(1): 4-5. [Mentions exhibition of collections of insects of Laysan and French Frigate Shoals by Fullaway, and at Laysan by W. A. Bryan in April 1911. No specific identifications are mentioned.] [POBSP 1630]

Anonymous. 1923. Ad club hears of rabbits, birds, turtles and glass gloves. Paradise of the Pacific 36, July 1923: 26. [Report of a talk by Garritt Wilder to the Northwestern Hawaiian Islands many years before [presumably in 1905]. Comments are made specifically about Laysan and Lisianski.] [POBSP 1279]

Anonymous. 1930. Wilder sails for Laysan to reclaim island. Honolulu Star-Bulletin, July 28 1930: 1. [G. P. Wilder left 28 July on the Pioneer to replant

vegetation on Laysan.]

Anonymous. 1937. Laysan Island - City and County of Honolulu. Paradise of the Pacific 49(9): 20, 31. [Brief history] [POBSP 1272]

Anonymous. 1939. Manure. The Sales Builder 12(1): 2-22.

Anonymous. 1951a. Rare Laysan Duck may be effecting comeback. Honolulu Star-Bulletin, July 30, 1951 (3): 4. [The Vanderbilt Expedition (with Vernon Brock) found 19 adult and 20 young ducks, 50 Bristle-thighed Curlews; other census data are briefly given.]

Anonymous. 1951b. The Laysan Island Cyclorama and late news from Laysan. ‘Elepaio 12(1): 1-2. [Description of cyclorama at Iowa State University. Notes on various expeditions to Laysan especially regarding changes in vegetation, rabbit and bird populations] [POBSP 772]

Anonymous. 1957. Two hardy scientists on lonely Laysan mission. Honolulu Advertiser, July 2, 1957: A3-1. [Brief report of D. H. Woodside and R. E. Warner leaving 22 June for Laysan]

Anonymous. 1966a. Photostation record, Hawaiian Islands National Wildlife Refuge (French Frigate Shoals, Laysan, Pearl and Hermes Reef), March 17 to April 5, 1966. [Unpubl. photographs available from Hawai‘i Dept. Land and Nat. Resources, Div. Forestry Wildl.; not seen, from Newman 1988]

Anonymous. 1966b. Rare birds. Honolulu Star-Bulletin, May 21, 1966: A-4. [Laysan Finch and Laysan Duck breed in Honolulu Zoo.]

Anonymous. 1966c. Rare birds. Honolulu Star-Bulletin, July 21, 1966: A-4: 1. [Photo of hatchlings and mother Laysan Duck in Honolulu Zoo]

Anonymous. 1966d. Hawaii’s other islands. Honolulu Star-Bulletin, December 20, 1966: D6: 1. [Good photo by Warren Roll of Laysan and of R. L. Walker. Estimates given of 10,000 Laysan Finch and 450-500 Laysan Ducks]

Anonymous. 1968. Leeward Islands rich in bird life. Part of Honolulu. Honolulu Advertiser, Nov. 17, 1968: A-10. [Interview with botanist D. Herbst about his trip which involved a visit to Laysan; photos of Laysan Albatross (*Diomedea immutabilis*) chick and flying Red-tailed Tropicbird.]

Anonymous. 1979. Laysan Island Bird Population Estimates 1979. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 8 pp.

Anonymous. 1985ms. Trip report - biological monitoring: Tern Island, French Frigate Shoals and Laysan Island 21 March - 14 April 1985. 7 pp. Unpublished report in the files of the Fish and Wildlife Service, Honolulu, HI. [Includes 3 1/4 page annotated list of 18 breeding species recorded during visit 1-10 April.]

Anonymous. 1992. Preliminary results of 1992 Northwestern Hawaiian Islands Hawaiian Monk Seal field season given. Southwest Fish. Sci. Cent. Rep. Activities, September-October 1992: 13-15. [Laysan, visited 20 March-26 July had second highest number of births (37) since 1983. Information given on survival, tagging, entanglement and mortality; of 11 seal deaths 7 were attributed to mobbing. Data also given for Kure, Midway, Pearl and Hermes Reef, Lisianski and French Frigate Shoals.]

Anonymous. 1993a. Preliminary results presented for 1993 Northwestern Hawaiian Islands Hawaiian Monk Seal field season. Southwest Fish. Sci. Cent. Rep. Activities, September-October 1993: 9-11. [Laysan, visited 16 April-26 June and 2 August had a total population of 204 seals 20 fewer than 1992. Forty two births recorded, the second highest since 1977. Information given on survival, tagging, entanglement and mortality; of 3 seal deaths none were attributed to mobbing. Data also given for Kure, Midway, Pearl and Hermes Reef, Lisianski, French Frigate Shoals and Necker and Nihoa islands]

Anonymous. 1993b. Oil spill mars Hawaiian Islands National Wildlife Refuge. 'Elepaio 53(5): 36. [Mentions oil on Laysan, first seen washing up on 26 March 1993 and eventually oiling five miles of the coastline with tar balls and clumps of oil and oiling 15 Hawaiian Monk Seals, but fortunately no birds.]

Anonymous. 1994a. Adult male Hawaiian Monk Seals removed from Laysan Island. Southwest Fish. Sci. Center Rep. Activities Third Quarter 1994: 8. [Mortality caused seals by mobbing of one another treated by removing excess males to localities near the main Hawaiian Islands in late July and early August 1994.]

Anonymous. 1994b. Preliminary results of 1994 Hawaiian Monk Seal field studies. Southwest Fish. Sci. Center Rep. Activities October-December 1994: 4-6. [Data on populatons, birth rate and survival, oiling and entanglements based on observations 23 March - 2 August. Data also given for seals at Kure, Midway, Pearl and Hermes Reef, Lisianski, and French Frigate Shoals.]

Anthony, A. W. 1924. The raided rookeries of Laysan, a belated echo. Condor 26(1): 33-34. [Of neglible value; suggests that the Red-tailed Tropicbird was formerly more common off western North America prior to depredations of this species on Laysan.] [POBSP 1141]

Aoki, J. 1964. Some oribatid mites (Acarina) from Laysan Island. Pacific Insects 6(4): 649-664. [Eight species listed from Laysan based on collections made in December 1963 all of which were previously unreported from the island. Five species,

Scapheremaeus sinuous, *Multioppia wilsoni*, *Hypozetes laysanensis*, *Ceratozetes incurvus*, and *Nesoribatula pacifica* are described as new with the latter also representing a new genus.] [POBSP 1610]

Aoki, J. 1965. Notes on the species of the genus *Epihohmannia* from the Hawaiian Islands (Acarina: Oribatei). Pacific Insects 7(2): 309-315. [Records 2 species from Laysan from specimens collected in December 1963] [POBSP 1607]

Applegate, J. 1992ms. Laysan Trip Report. (January 27 to April 20, 1992). Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 17 pp (and 35 unnumbered pp. of notes). [Report of visit by author and A. K. Kepler whose primary objective was to exterminate the exotic grass *Cenchrus echinatus*. Data provided include counts of the Laysan Duck, banding and color tagging of Laysan (*Diomedea immutablis*) and Black-footed (*Diomedea nigripes*) chicks, measurements of rainfall and salinity of lagoon and adjacent standing water, observations of ticks, the endemic plant, *Mariscus pennatiformis bryanii*, and the "Dead Zone" (an area of the island where dead albatross chicks, dead crabs and dead flies are found together with disturbing frequency)].

Atkinson, A. L. C., and W. A. Bryan. 1913. A rare seal. New York Zool. Soc. Bull. 16: 1050-1051. [POBSP 1602]

Atkinson, S., and W. G. Gilmartin. 1992. Seasonal testosterone pattern in Hawaiian monk seals. J. Reprod. Fertil. 96(1): 35-39. [Studies in Oahu of four adult males collected on Laysan in May 1987. Figure 2 shows number of pups born monthly and in part is based on previously unpublished data; Figure 3, based on previously unpublished data shows numbers of females exhibiting mating injuries by month 1988-1990.]

Atkinson, S., B. L. Becker, T. C. Johanos, J. R. Pietraszek, and B. C. S. Kuhn. 1994. Reproductive morphology and state of female Hawaiian Monk Seals (*Monacus schauinslandi*) fatally injured by adult male seals. J. Reprod. Fertility 100(1): 225-230. [Based on seals killed at Laysan most attacks occur during oestrus.]

Baar, R. 1903. Hornschwämme aus dem Pacific. Ergebnisse einer Reise nach dem Pacific, Schauinsland, 1896-97. Zool. Jahrb. Syst. 19: 27-36. [Reports 2 species of demospongiid sponges: *Euspongia irregularis* and *Hippospongia densa*. Author's name misspelt as Barr in Ely and Clapp 1973.] [POBSP 1585]

Bailey, A. M. 1918. The Monk Seal of the South Pacific. Am. Mus. J. 18(5): 396-399. [Notes collection of a seal by the Biological Survey expedition of 1912-1913] POBSP 1226]

Bailey, A. M. 1919. Notes on our Hawaiian reservations. Natural History 19: 382-395.

Bailey, A. M. 1934. Wanderers of the seas: albatrosses which nest on coral and volcanic rocks in the Pacific Ocean. Nat. Hist. 34: 273-281.

Bailey, A. M. 1942. The portulaca flats of Laysan. Aud. Mag. 44: 150-161. [Popular notes on Laysan birds, with photographs] [POBSP 1005]

Bailey, A. M. 1951. Nature photography with miniature cameras. Denver Mus., Mus. Pict. 1: 1-62. [Includes three photographs of the birds of Laysan] [POBSP 508]

Bailey, A. M. 1952a. Laysan and Black-footed Albatrosses. Denver Mus. Nat. Hist., Mus. Pict. 6. 80 pp. [POBSP 12]

Bailey, A. M. 1952b. The Hawaiian monk seal. Denver Mus. Nat. Hist., Mus. Pict. 7. 32 pp. [Summarizes earlier information and gives original information on seal collected December 1912 and on two seals collected by the Tanager Expedition. Also original observations made in December 1936 and a seal count made in June 1951] [POBSP 288]

Bailey, A. M. 1956. Birds of Midway and Laysan Islands. Denver Mus. Nat. Hist., Mus. Pict. 12. 130 pp. [POBSP 3]

Bailey, A. M., and R. J. Niedrach. 1951. Stepping stones across the Pacific. Denver Mus. Nat. Hist., Mus. Pictorial 3. 63 or 4-47 pp. [Most information is on a visit to Midway in 1949 but also gives some information on Laysan] [POBSP 274]

Bailey-Brock, J. H., and O. Hartman. 1987. Class Polychaeta. Pp. 216-454 in D. M. Devaney and L. G. Eldredge (eds.). Reef and Shore Fauna of Hawaii. Section 2: Platyhelminthes through Phoronida and Section 3: Siphuncula through Annelida. B. P. Bishop Spec. Publ. 64(2 and 3), Honolulu, HI. [Reidentifies (p. 240) Treadwell's (1906) identification of *Thaleness oculata* at Laysan as *Euthaleness chacei* Pettibone, 1970.]

Baker, G. E., and J. A. Meeker. 1972. Ecosystems, mycologists, and the geographical distribution of fungi in the central Pacific. Pacific Sci. 26(4): 418-432. [Lists *Sporomia minima* Auerswald from collections made on Laysan 7, 11 September 1968 by Derral Herbst.]

Bakus, G. J. 1979. Wildlife Refuges and Endangered Species of the Hawaiian Islands and the Trust Territory of the Pacific Islands. *In* J. E. Byrne (ed.). Literature Review and Synthesis of Information on Pacific Island Ecosystems. U.S. Fish & Wildlife Service FWS/OBS-79/35: 1-106. [Discusses Laysan in 2-3 places, summarizing data on status and populations of seabirds, rails, mammals, Laysan Finch, etc.]

Balazs, G. H. 1975. Green Turtle's uncertain future. Defenders 50(6): 521-523.

[Laysan is mentioned but only in a very minor way; most comments are about French Frigate Shoals.]

Balazs, G. H. 1976. Green turtle migrations in the Hawaiian Archipelago. Biol. Conserv. 9: 125-140.

Balazs, G. H. 1979. Revised bibliography of the Hawaiian Monk Seal, *Monachus schauinslandi* Matschie 1905. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-79-03.

Balazs, G. H. 1980a. A review of basic biological data on the Green Turtle in the Northwestern Hawaiian Islands. Pp. 42-54 *in* R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigation in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. UNIHI-Seagrant-MR-80-04. [Most observations reported were at French Frigate Shoals but Laysan is mentioned and a map documents movements of adults from Lisianski to Laysan and from Laysan to French Frigate Shoals.]

Balazs, G. H. 1980b. Synopsis of biological data on the Green Turtle in the Hawaiian Islands. U.S. Dep. Comm. NOAA-TM-NMFS-SWFC 7. ix & 141 pp. [Much as above]

Balazs, G. H. 1981. Status of sea turtles in the central Pacific Ocean. Pp. 243-252 in K. A. Bjorndal (ed.). Biology and Conservation of Sea Turtles. Smithsonian Inst. Press/World Wildlife Fund, Washington D.C. [On p. 245 notes decline in basking and foraging aggregations at Laysan and Lisianski islands, and, to a lesser extent, at Pearl and Hermes Reef]

Balazs, G. H., H. F. Hirth, P. Y. Kawamoto, E. T. Nitta, L. H. Ogren, R. C. Wass, and J. A. Wetherall. 1990. Draft recovery plan for Hawaiian sea turtles. Hawaiian Sea Turtle Recovery Team, Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. 73 pp.

Balazs, G. H., H. F. Hirth, P. Y. Kawamoto, E. T. Nitta, L. H. Ogren, R. C. Wass, and J. A. Wetherall. 1992. Interim recovery plan for Hawaiian sea turtles. Southwest Fish. Sci. Cent. Admin. Rep., Honolulu, Admin. Rep. H-92-01. 76 pp. [Most of material specifically mentioning islands refers to the Green Turtle at French Frigate Shoals. P. 17 has a map showing Green Turtle movements in Hawaii including ones from Pearl and Hermes Reef to Laysan and back and forth between Laysan and French Frigates Shoals.]

Balazs, G. H., and G. C. Whittow, 1978. Bibliography of the Hawaiian Monk seal, *Monachus schauinslandi* Matschie 1905. Univ. Hawaii Inst. Marine Biol. Tech. Rep. No. 35. 27 pp.

Balcomb, K. C. 1966ms a. Summary report on the status of the Hawaiian monk seal *Monachus schauinslandi* - Laysan and Lisianski Islands, 10-22 June 1966. 7 pp. [SIA 245, Ser 7, 17, 8]

Balcomb, K. C. 1966msb. Preliminary report, Laysan Island, October 1966. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 13 pp. [Notes and estimates for 28 species of birds, turtles and skinks, and Hawaiian Monk Seal; table lists numbers of birds banded and collected] [POBSP BB 8/ SIA 37, 163, 17]

Baldwin, P. H. 1945. Fate of the Laysan Rail. Audubon. Mag. 47: 343-348. [Popular account summarizing history on Laysan and introduction and eventual extirpation from Midway Atoll] [POBSP 999]

Baldwin, P. H. 1947. The life history of the Laysan Rail. Condor 49(1): 14-21. [POBSP 964]

Ball, D. L., and J. A. Gervais. 1992ms. Trip Report: Laysan Island 17 July - 12 November 1992. Admin. Rept., U. S. Fish Wildl. Service, Honolulu, HI. 19 pp. [Reports on *Cenchrus* control; gives an annotated list of breeding birds; results of 4 shorebird censuses; notes on arthropods, vascular plants, and rainfall. Also gives a list of vagrants and dates these were seen but with no other details; the most unusual of these were a Great Crested Tern (*Sterna bergii*) seen 22 August and 5 September, a Ruff (*Philomachus pugnax*) seen 7-13 September and 23-26 October, a Semipalmated Plover (*Charadrius semipalmatus*) seen 7 and 26 September, and a Bufflehead (*Bucephala albeola*) seen 7 November. Specimens of Laysan Finch, Laysan Duck and a Sooty Storm Petrel (*Oceanodroma tristrami*) and some non-avian material were collected.]

Ball, S. C. (ms.). Field notebook kept during the 1923 Tanager Expedition. B. P. Bishop Museum, Honolulu. [Miscellaneous notes on fish, birds, etc.] [POBSP 1757]

Ballou, R. M. 1981. The Leeward Islands. Pacific Discovery 34(4): 14-25. [Narrative of trip west along Leewards in September 1980 or 1981 on the USCG Buttonwood. Ca. one page is on Laysan, but the only original information is about the kinds of work done by the USFWS.]

Banish, L. D., and W. G. Gilmartin. 1987. Preliminary investigation: hematology and serum chemistry of the young Hawaiian Monk Seal, *Monachus schauinslandi*. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-87-13. 10 pp.

Banish, L. D., and W. G. Gilmartin. 1988. Hematology and serum chemistry of the young Hawaiian Monk Seal (*Monachus schauinslandi*). J. Wildl. Dis. 24(2): 225-230.

Banish, L. D., and W. G. Gilmartin. 1992. Pathological findings in the Hawaiian Monk Seal. J. Wildl. Dis. 28(3): 428-434. [Necropsies of Monk Seals collected 1981-1985 at Kure, Pearl and Hermes, French Frigate Shoals, Lisianski, Laysan, and Necker.]

Banks, R. C., and R. C. Laybourne. 1977. Plumage sequence and taxonomy of Laysan and Nihoa finches. Condor 79(3): 343-348. [Based in part on a series of specimens collected on Laysan in 1967.]

Barclay, S. D. 1991ms. Trip Report: Laysan, June 10 - November 8, 1991. Admin. Rep., U.S. Fish & Wildlife Service, Honolulu, Hawaii. 25 pp (and 6 unnumbered pp of notes and data). [Since 1991 there have been several trip reports by personnel continuously on Laysan controlling the weedy sand bur, *Cenchrus echinatus*). This report included the first assessment of *Cenchrus* damage and the initial plans to begin its management. It also includes a brief annotated list of the birds, results on censuses of the Laysan Duck, notes on turtles, seals, other vegetation, the "dead zone", marine debris, and level of the lake.]

Barclay, S. D. 1992ms. Laysan Cenchrus Project Condition (January 26 - February 3, 1992). Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 5 pp.

Bargar, K. E., and E. D. Jackson. 1974. Calculated volumes of individual shield volcanoes along the Hawaiian-Emperor chain. J. Res., U. S. Geol. Survey 2(5): 545-550. [Main and all of Northwestern Hawaiian Islands including Laysan.]

Bassham, B. L. 1936 ms. Cruise report of the *Reliance* for March 1936. Rec. Group 26, U.S. Nat. Arch. 2 pp. [Itinerary of visits to Nihoa, Necker, French Frigate Shoals, and Laysan, the latter visited 6-8 March. Rabbits were not seen and were thought to have become extirpated.] [POBSP 1736]

Bauer, D., and V. Gauger. 1994ms. Trip Report: Laysan Island 07 November 1993 - 12 June 1994. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, HI. 27 pp. and 15 unnumbered pp. of figures and notes. [Data on *Cenchrus* control, estimations of nesting Black-footed and Laysan Albatrosses from transect censuses, censuses of Laysan Ducks, island wide counts of nests of Black Noddies, results of monthly shorebird counts, annotated list of breeding and vagrant birds, annotated list of vascular plants, and notes on the "dead zone", lake conditions, monk seals, and weather. Nesting distributions Black Noddy mapped]

Bauer, E. A. 1972a. Hawaiian Islands National Wildlife Refuge. Sea Frontiers 18(6): 346-356. [Report of USFWS survey trip west along the Leewards in September 1971. Has ca. 3 pp on Laysan; also mentions Lisianski, Gardner Pinnacles, French Frigate Shoals, Necker and Nihoa.]

Bauer, E. A. 1972b. Voyage of the Buttonwood. Outdoor Life, May 1972, pp. 57-59, 118, 120, 122. [Another account of the 1971 trip with part of p. 120 devoted to Laysan.]

Bauer, E. A. 1972c. The unknown Hawaiian Islands. Animals 15: 496-503. [Yet another account of the 1971 trip of the *Buttonwood*; two-three pages of text and photographs on Laysan.]

Baylis, J. S. 1934 ms. Cruise report for the *Itasca* for the month of June 1934. Rec. Group 26, U.S. Nat. Arch. 6 pp. [Itinerary of visits to the Northwestern Hawaiian Islands with a few notes on birds, seals, and turtles on Laysan (visited 26 June), and the other islands] [POBSP 1547]

Bean, E. 1985ms a. Trip report - Laysan Island, 1 April - 21 July 1985. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 24 pp. [Includes notes on nesting species and maps of Red-footed Booby (*Sula sula*), Sooty and White tern nesting locations.]

Bean, E. 1985ms b. Laysan Report: Laysan Drift Fence, October 2 - October 16, 1985. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 7 pp.

Bean, E., D. Hu, and R. [L.] Pyle. 1985ms. Trip report - Biological monitoring: Tern Island, French Frigate Shoals and Laysan Island 21 March - 14 April 1985. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 29 pp. [Laysan visited 1-10 April. Report gives ca. 3 pp. annotated list of breeding birds seen; censues were also made of Great Frigatebirds, Red-footed Boobies, Laysan Finches and Laysan Ducks, and a map indicates nesting areas of the Red-footed Booby.]

Beardsley, J. W. 1966. Insects and other terrestrial arthropods from the Leeward Hawaiian Islands. Proc. Haw. Entomol. Soc. 19(2): 157-185. [Gives lists of arthropods collected in September 1964 at Nihoa, Necker, French Frigate Shoals, Lisianski, Pearl and Hermes Reef, and Kure Atoll. Comments are made on several species at Laysan including the first record for a spider, *Chiracanthium diversum* L. Koch, and one for a lizard, *Ablepharus boutonii*.] [POBSP 1559, 1799]

Beccari, O, and J. F. Rock. 1921. A monographic study of the genus Pritchardia. Mem. B. P. Bishop Mus. 8(1): 1-77. [Notes occurrence, p. 13, of *Pritchardia*, probably *P. remota*, on Laysan]. [POBSP 579]

Becker, B. L., P. A. Ching, L. M. Hiruki, and S. A. Zur. 1994. The Hawaiian Monk Seal on Laysan Island, 1987 and 1989. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-MNFS-SWFSC-213. 20 pp. [Data on populations, behavior, reproduction, factors affecting survival and interatoll movement from visits 8 April-20 July 1987 and 30 March-16 July 1989. Excluding pups, beach counts in 1987 averaged 130.1 individuals (n = 26) and in 1989 averaged 82.8 individuals (n = 26). Tables 5A

and 5B (p. 18) summarize movements during these years. Six, 7, and 1 movements involved seals moving to Laysan from French Frigate Shoals, Lisianski and Pearl and Hermes Reef, respectively, and 5, 4, and 1, were recorded as moving to these same islands, respectively.]

Becker, B. L., J. R. Klavitter, L. P. Laniawe, W. A. Machado, T. J. Ragen, and Molly B. Tarleton. 1995. The Hawaiian Monk Seal on Laysan Island, 1992. Pp. 23-36 *in* T. C. Johanos, C., L. M. Hiruki, and T. J. Ragen. The Hawaiian Monk Seal in the Northwestern Hawaiian Islands, 1992. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-128. 128 pp. [Data from a visit 23 March-25 July 1995 on populations, reproduction, factors affecting survival, and interatoll movement. Tables 3.5a and 3.5b (p. 35) summarize 1992 movements without giving details. Six, 4, and 1 movements involved seals moving to Laysan from French Frigate Shoals, Lisianski and Pearl and Hermes Reef, respectively, and 9 and 5, were recorded as moving to French Frigate Shoals and Lisianski, respectively.]

Becker, B. L., R. J. Morrow, and J. K. Leialoha. 1989. Censuses and interatoll movements of the Hawaiian Monk Seal on Laysan Island, 1985. U.S. Dep. Comm., NOAA Tech. Memo. NMFS-SWFC-135. 25 pp. [Data from survey conducted from 2 March to 30 November 1985. Excluding pups, 86 censuses ranged from 76-147 animals ($\bar{x}$ = 117.6), an increase of almost 20% from the preceding year. Table 1 lists movements of 9 animals in 1985, involving movements to and from Lisianski and French Frigate Shoals with a net gain of 3 animals to the Laysan population.]

Becker, B. L., K. E. O'Brien, K. B. Lombard, and L. P. Laniawe. 1995. The Hawaiian Monk Seal on Laysan Island, 1991. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-215. 16 pp. [Data obtained on populations, reproduction, interatoll movement and factors affecting survival from visit 31 March-22 July. Excluding pups, 37 censuses averaged 69.1 individuals, with a total spring population of 248 seals. There were 3, 4, and 1 movements to Laysan from French Frigate Shoals, Lisianski and Pearl and Hermes Reef, respectively and 3, 4 and 1 movements to these islands, respectively.]

Benson, B. 1970. Island refuge chain is off limits. Honolulu Advertiser, October 13, 1970: C-8. [Excerpts from trespasser's journal 8-17 April 1970]

Benson, B. 1973. Laysan Island, the last refuge. Honolulu Advertiser, April 8, 1973. H-4. [Not seen; a popular account with two pictures vide Bryan 1978]

Berger, A. J. 1970a. The present status of the birds of Hawaii. Pacific Sci. 24(1): 29-42. [Briefly discusses each of the endemic birds of Laysan]

Berger, A. J. 1970b. The Leeward Islands. Oceans, 3(15: 22-33. [Account of two Leeward surveys in 1966 with 3-4 pp. devoted to Laysan.]

Berger, A J. 1981. Hawaiian Birdlife. University Press of Hawaii, Honolulu. Second edition. 260 pp. [Section on Laysan Island with several references to birds there.]

Bergh, R. 1900. Ergebnisse einer Reise nach dem Pacific (Schauinsland, 1896-97). Die Opisthobranchier. Zool. Jahrb., Syst. 13: 207-246. [Three species reported from Laysan: *Chelidonura hirundinina* (Q. et G.) var. *elegans* subsp. nov.; *Samla annuligera* gen. et sp. nov; Bgh., *Phyliroë atlantica* Bgh.] [POBSP 1592]

Bergman, C. 1991. Rescuing Hawaii's "brine children" with a head start. Smithsonian 22(9): 86-97. [Provides a few remarks on information about monk seals on Laysan; most of remarks deal with French Frigate Shoals]

Berry, S. S. 1910. Diagnoses of new cephalopods from the Hawaiian Islands. Proc. U.S. Nat. Mus. (No. 1713): 407-419. [Includes two species recorded by Schauinsland.]

Bitter, G. 1900. Die phanerogamische Pflanzenwelt der Insel Laysan. Abh. Nat. Ver. Bremen 16: 430-439. [Reports 26 species of vascular plants collected by Schauinsland; two are described as new species: *Solanum laysanense* [= *Solanum nelsoni*], *Phyllostegia* [= *Eragrostis*] *variabilis*] [POBSP 368, English translation]

Boersma, P. D. 1986. Ingestion of petroleum by seabirds can serve as a monitor of water quality. Science, 231(4376): 373-376. [Some samples came from Laysan]

Boness, D. 1990. Who's the mother. Fostering behavior in endangered Hawaiian Monk Seals. Zoogoer 19(3): 10-13. [Laysan mentioned in a minor way in comparisons to observations in a study made at French Frigate Shoals.]

Boswell, M., and B. S. Keitt. 1995ms. Trip Report: Laysan Island, 17 October, 1994 - 11 March, 1995. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, HI. 35 pp. [Information on *Cenchrus* control, estimates of population size of breeding albatross, census of Laysan Ducks, results of monthly shorebird surveys, notes on nesting by Red-tailed Tropicbirds and Black Noddies, notes on breeding birds, plants, weather, vagrant birds and lake level. The most notable reports of vagrants were a Yellow-billed Cuckoo (*Coccyzus erythrophthalmus*) seen 1 November and Black Terns (*Chlidonias niger*) seen 21 December 1994 and 11 January and thought to be different individuals.]

Brand, A. 1913. Hydrophyllaceae. Pflanzenreich IV, 251 (Heft 59): 1-210. [On p 152 describes var *laysanicum* of *Nama sandvicense*.]

Brennan, J. M., and A. B. Amerson, Jr. 1971. Six new species and additional records of chiggers from the central Pacific (Acarina: Trombiculidae). J. Parasitol. 57(6): 1311-1317. [Includes records from Laysan including paratypes of *Schoengastia pobsa* sp. n. from Laysan Finch on Laysan 11 June 1966. Also records for Wake and

Baker Islands, Johnston Atoll, and the Phoenix, Line and Marshall Islands.]

Brock, V. E. 1951a. Some observations on the Laysan Duck, *Anas wyvilliana laysanensis*. Auk 68(3): 371-372. [Count of birds 23 June 1950 compared with counts obtained in 1911, 1925, and 1936] [POBSP 976]

Brock, V. E. 1951b. Laysan Island bird census. 'Elepaio, 12(3): 17-18. [Compares count made during one day in 1951 with those made by Dill in 1911.] [POBSP 773]

Brooks, N. C. 1859a. Cruise of the Gambia. Pacific Comm. Advertiser, 11 Aug. 1859.

Brooks, N. C. 1859b. "Laysan Island with track of U.S. Bark Gambia, N. C. Brooks, Commander . . . Wood, water, seals, turtle, fish, fouls, and eggs...'7 Scale 1 inch to 1/3 mile. 16 1/2 x 12 1/2 inches. Filed as 272.8, records of the Hydrographic Office, in Nat.Archives. Fide: H. R. Friis, 1961. U.S. Scientific Geographical Exploration of the Pacific Basin 1783-1899. [(An exhibit prepared for the Tenth Pacific Science Congress, Honolulu, 1961.]

Brooks, N. C. 1860. Islands and reefs west-north-west of the Sandwich islands. Pacific. Naut. Mag. 29: 499-504. [Pp. 500-501 describe Laysan as seen during a visit in May 1859; states he collected 25 varieties of plants, that reefs there had abundant fish and turtle, and that the guano deposit was too small to make it worth mining] [POBSP 487]

Brown, J. H. 1914 ms. Report to the Captain Commandant of the Revenue Cutter Service of a cruise to the "Bird Islands" in September 1914. Unpublished ms. material, Rec. Group 26, U.S. Nat. Arch. 4 pp. [Landings made on Bird (Nihoa), Necker, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes Reef and Midway with no evidence of bird poachers being found. Notes decrease in rabbits at Laysan and Lisianski with only two live animals seen at the latter island.] [POBSP 1547]

Brown, J. H. 1915 ms. Report to the Captain Commandant of the Coast Guard of observations made during a cruise to Laysan, Lisianski, etc., in March 1915. Rec. Group 26, U.S. Nat. Arch. 14 pp. [Landings made from the *Thetis* at most of the Northwestern Hawaiian Islands. Brown made estimates of bird populations at Nihoa and French Frigate Shoals and reported that Laysan had been visited by raiders who had slaughtered a great number of birds.] [POBSP 1547]

Brown, J. H. 1916 ms. Report to the Captain Commandant of the Coast Guard of the Cruise made to the Hawaiian Bird Reservation in February 1916. Rec. Group 26, U.S. Nat. Arch. 12 pp. [Provides some details of visits to Northwestern Hawaiian Island in addition to those made by Munter.] [POBSP 1547]

Browne, R. A., C. R. Griffin, P. R. Chang, M. Hubley, and A. E. Martin. 1993. Genetic divergence among populations of the Hawaiian Duck, Laysan Teal, and Mallard. Auk 110(1): 49-56. [Gives 1978 population estimate for the Laysan Teal that may not have been published elsewhere]

Bryan, E. H., Jr. 1926a. Introduction [to Insects of Hawaii...]. Bernice P. Bishop Mus. Bull. 31: 3-16. [General description of atolls with table listing species known from each of the islands.]

Bryan, E. H., Jr. 1926b. Coleoptera. Pp. 46-49 *in* E. H. Bryan, Jr. et al. 1926. [Lists 5 species from Laysan]

Bryan, E. H., Jr. 1926c. Diptera. Pp. 67-71 *in* E. H. Bryan, Jr. et al. 1926. [Lists 10 species from Laysan from specimens collected there in 1923]

Bryan, E. H., Jr. 1926d. Orthoptera, Blattidae. P. 89. *in* E. H. Bryan, Jr. et al. 1926. [Lists 1 roach from Laysan from specimens collected there in 1923]

Bryan, E. H., Jr. 1926e. Other orders. Pp. 90-91. *in* E. H. Bryan, Jr. et al. 1926. [Specimens from a variety of orders were reported from Laysan from April 1923 collections but only one Embiidina was (questionably) identified to species]

Bryan, E. H., Jr. 1926f. Insects of the Tanager Expedition. B. P. Bishop Mus. Spec. Publ. 11: 31. [Brief abstract mentioning insect fauna in relation to ecological conditions]

Bryan, E. H., Jr. 1932. Notes and exhibitions. Flies from Laysan Island. Proc. Haw. Entomol. Soc. 8(1): 3. [Reports 4 species collected on Laysan in August 1930] [POBSP 1605]

Bryan, E. H., Jr. 1934. A review of the Hawaiian Diptera, with descriptions of new species. Proc. Haw. Entomol. Soc. 8(3): 399-468. ["About 325 species" are discussed and tabulated, among them 5 species then known from Laysan: *Hydrophorus pacificus*, *Lucilia graphita*, *Limosina venalicia*, *Scatella sexnotata*, and *Olfersia spinifera*.]

Bryan, E. H., Jr. 1935. Hawaiian Nature Notes. Honolulu Star Bulletin, Ltd., Honolulu. 285 pp. [Chapter on NW Hawaiian Islands and story of "old stump leg", a "pet" Golden Plover (*Charadrius dominica*) of Max Schlemmer's on Laysan.]

Bryan, E. H., Jr. 1938. Laysan, an island of Hawaii. Paradise of the Pacific 50(6): 21, 28-31. [Popular account of history and natural history; photograph shows the desolate condition of the island in 1923 when the island had been largely denuded of vegetation by rabbits] [POBSP 427]

Bryan, E. H., Jr. 1939. We see only the peaks.. Paradise of the Pacific 50(12), 13-16. [General description of the Northwestern Hawaiian Islands with several paragraphs on Laysan.] [POBSP 414]

Bryan, E. H., Jr. 1942. American Polynesia and the Hawaiian Chain. Tongg Publ. Co., Honolulu. 253 pp. [POBSP 98]

Bryan, E. H., Jr. 1954. The Hawaiian Chain. B.P. Bishop Mus. Press, Honolulu. iii and 71 pp. [POBSP 88]

Bryan, E. H., Jr. 1956. Plants record from Laysan and Midway islands. Pp 18-21 in Bailey, A. M., Birds of Midway and Laysan Islands. Denver Mus. Nat. Hist., Mus. Pictorial 12.

Bryan, E. H., Jr. 1958. Check list and summary of Hawaiian birds. Books about Hawaii, Honolulu. 28 pp. [Check list notes occurrence of many vagrants at Laysan to date of publication of list.] [POBSP 4]

Bryan, E. H., Jr. 1964. Gulls on Pacific Islands. 'Elepaio, 24(11): 53-54. [Mentions Laysan but apparently only secondary information.] [POBSP 933]

Bryan, E. H., Jr. 1978. The Northwest Hawaiian Islands: An Annotated Bibliography. U.S. Fish & Wildlife Service, Honolulu, Hawaii. April, 1978. 136 pp. [A more than usually valuable bibliograpy with useful annotations, based to a fair degree on Atoll Research Bulletins published on these islands 1969-1974 (and faithfully incorporating some errors in those sources). Gives one or two page summary on each island, a map, and a check-list indicating occurrance on each island for mammals, birds, and plants]

Bryan, E. H., Jr. et al. 1926. Insects of Hawaii, Johnston Island and Wake Island. B. P. Bishop Mus. Bull. 31: 94 pp. [Includes papers by a number of authors that are included elsewhere in this bibliography] [POBSP 19]

Bryan, E. H., Jr., and J. C. Greenway, Jr. 1944. Contribution to the ornithology of the Hawaiian Islands. Bull. Mus. Comp. Zool., Harvard 94: 79-142. [Brief history of ornithology in Hawaii with a detailed distributional list that includes some previously unpublished material. Laysan is mentioned frequently but usually derivatively. Original information for Laysan includes a count of 9 Laysan Ducks in 1936, the mention of a Harlequin Duck (*Histrionicus histrionicus*) specimen from a 1906 collection, and occurrence of Black-legged Kittiwake (*Rissa tridactyla*) from fragments in the Bishop Museum collection; a lapsus lists the Laysan Finch as extinct.]

Bryan, W. A. 1910. Bird slaughter on the Pacific islands. Bird Lore 12( ): 90-93.

Bryan, W. A. 1911. Laysan Island, a visit to Hawaii's bird reservation. Mid-

Pacific Mag. 2(4): 303-315. [Description of Laysan, particulary vegetation and birds with several photographs] [POBSP 277]

Bryan, W. A. 1912. The introduction and acclimatization of the Yellow Canary on Midway Island. Auk 29(3): 339-342. [Details importation to Midway of Laysan Finches obtained on Laysan in May and September 1905] [POBSP 973]

Bryan, W. A. 1915. Natural history of Hawaii. Hawaiian Gazette Co., Ltd., Honolulu. 596 pp. [Popular account with geographic notes on Northwestern Hawaiian Islands atolls in Chapter 8 and account of birds in Chapter 23] [POBSP 216]

Butler, G. D., Jr. 1961a. Stratiomyiid fly associated with dead albatrosses on Laysan Island. Proc. Haw. Entomol. Soc. 17(3): 331-332. [Observations of *Brachycara latifrons* James in July 1959] [POBSP 1539]

Butler, G. D., Jr. 1961b. Insects and other arthropods from Laysan Island. Proc. Haw. Entomol. Soc. 17(3): 379-387. [Summarizes earlier reports and reports 68 insects, an isopod, 3 species of Acarina, and 5 Araneida from collections made in April and July 1959.] [POBSP 1195]

Butler, G. D., Jr., and M. D. F. Udvardy. 1966. Basking behavior of the Hawaiian monk seal on Laysan Island. J. Wildl. Manage. 30: 627-628. [Observations made in July 1959] [POBSP 1538]

Butler, G. D., Jr., and R. L. Usinger. 1963. Insects and other invertebrates from Laysan Island. Atoll Res. Bull. 98: 1-30. [Summarizes records from earlier literature and additional collections made by the authors in September 1961 and by John W. Beardsley in June 1962. Lists ca 189 species from Laysan, mostly insects, but including 2 land-snails, 6 Acarina, 7 spiders, 1 isopod, 1 chilopod, and 81 insects, some not determined to species and or genus. There are first reports for the atoll for 3 Acarina and 2 Araneida.] [POBSP 1366]

Byrne, J.E. 1979. Literature Review and synthesis of Information on Pacific Island Ecosystems. Coastal Ecosystems Project, Biological Services Program, U. S. Fish & Wildlife Service, Washington, D.C. FWS/OBS-79/35. [Includes Hawaii with some mention of the Hawaiian Islands' NWR]

Cairns, S. D. 1978. *Distochopora* (*Haplomerismos*) *anceps*, a new Stylasterine coral (Coelenterata: Stylasterina) from deep water off the Hawaiian Islands. Micronesica 14(1): 83-87. [Species described from four specimens taken offshore Laysan 27 July 1972]

Cairns, S. D. 1984. New records of ahermatypic corals (Scleractinia) from the Hawaiian and Line Islands. B. P. Bishop Mus. Occ. Pap. 25(10): 1-30. [Apparently includes at least one new record from Laysan Island].

Carlquist. S. 1965. Island Life: A Natural History of the Islands of the World. The Natural History Press, Garden City, New York. 451 pp. [Photo on p. 225 of stuffed Laysan Rails (*Porzana palmeri*) in chapter on flightless or near flightless fauna of islands.]

Carlquist, S. 1974. Island Biology. Columbia Univ. Press, New York, NY. 660 pp. [Derivative, but copious information about Laysan biota]

Carlquist, S. 1980. Hawaii, a Natural History. 2nd ed. Hawaii, Kauai: Pacific Tropical Botanical Garden. 468 pp. [lst edition was 1970, Natural History Press, Garden City, NY. 463 pp. [Chapters are devoted to each of the Northwestern Hawaiian Islands. The chapter on Laysan contains many B&W photos including ones of extinct endemic birds and the endemic plant *Nama sandwicensis* var. *laysanicum*.]

Caspers, H. 1968. Biology of a hypersaline lagoon in a tropical atoll island (Laysan). Pp. 326-333 *in* R. Misra and B. Gopal (eds.). Proc. Symp. on Recent Advances in Tropical Ecology. Internatl. Soc. Trop. Ecol., Varanasai, India. [Mostly on relationship of Laysan Duck and epydrid flies]

Caspers, H. 1981. On the ecology of the hypersaline lagoons on Laysan Atoll and Kauai Island, Hawaii, with special reference to the Laysan Duck, *Anas laysanensis* Rothschild. Hydrobiologia 82: 261-270.

Cate, J. M. 1963. Revision of Dall's Hawaiian mitrids with descriptions of three new species. Veliger 6(1): 23-43. [The type series of *Vexillum kewaloensis* sp. nov. includes a specimen from Laysan; also mentioned as occurring on Laysan is *Pusia alveolus* Reeve 1845.]

Cernohorsky, W. 1976. The Mitridae of the world. Part I. The subfamily Mitrinae. Indo-Pacific Mollusca 3(17): 273-528. [Records *Mitra* (*Strigatella*) *typha* Reeve 1845 from Laysan Island from a USNM specimen (p. 501); all other Northwestern Hawaiian Islands records for other species are from Midway Atoll.]

Chamberlain, R. V. 1926. Chilopoda. Pp. 92-94 *in* E. H. Bryan, Jr. et al. 1926. [*Honuaphilus alohanus* sp. nov. is reported from April 1923 collections on Laysan and other Northwestern Hawaiian Islands] [POBSP 339]

Chang, P. R. 1990. Strategies for managing endangered waterbirds on Hawaiian National Wildlife Refuges. M.S. thesis, Univ. Mass. 87 pp. [Not seen but probably mentions Laysan.] WR 225

Chapin, E. A. 1925. Descriptions of new internal parasites. Proc. U.S. Nat. Mus. 68 (No. 2603): 1-4. [Nematode *Contracaecum turgidum* described as new species, cestode, *Bothriocephalus* sp.? reported from a Hawaiian Monk Seal collected at Laysan by Wetmore 8 April 1923 during the Tanager Expedition] [POBSP 1590]

Ching, P. 1994. The Hawaiian Monk Seal. Honolulu, Univ. Hawaii Press. v & 40 pp. [Popular picture book on habits and conservation of the seal. The only specific mention of Laysan is a picture of on p. 31 of gray reef sharks just offshore]

Christiansen, K., and P. Bellinger. 1992. Insects of Hawaii. Vol. 15. Collembola. Univ. Hawaii Press, Honolulu. viii + 445 pp. [Records from Kure, Midway, Pearl and Hermes Reef, Laysan, French Frigate Shoals and Nihoa; four species are listed from Laysan, three from specimens, *Oudemansia esakii* (Kinoshita) p. 61, collected 24 July 1983, *Seira terrestris* (Folsom) p. 270, based on a 1961 Butler specimen, and, *Cyphoderus similis* Folsom, p. 316, collected 26 July 1983, as well as a putatative record of *Entomobrya* (*Entomogrya*) *griseoolivata* (Packard), p. 212, based on a report by Butler and Usinger (1963).]

Christophersen, E. and E. L. Caum. 1931. Vascular plants of the Leeward Islands, Hawaii. B.P. Bishop Mus. Bull. 81. 41 pp. [Reports 24 species of vascular plants collected by the Tanager Expedition and summarizes records and observations from visits in 1896, 1902, 1903, and 1911] [POBSP 513]

Clapp, R. B. 1968ms. Leeward survey No. 22, Preliminary report, Laysan report, Laysan Island. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 15 pp. [Notes and estimates for 26 species of birds, reptiles, and Hawaiian Monk Seal, the census of the latter obtained by USFWS personnel; also provides notes on seal tagging and a list of seals tagged and returned] [POBSP BB 8]

Clapp, R. B. 1969ms. [Extract of unpublished material in the U. S. Fish and Wildlife Service Office, Honolulu] 14 pp, typescript. [Data from 3 x 5 file cards that include extracts from unpublished reports that may otherwise no longer exist. Brief notes on birds from George Willet's Report on the Bureau of Biological Survey Expedition to the Northwestern Hawaiian Islands in 1912-1913 include remarks on birds on Necker, Nihoa, French Frigate Shoals, Lisianski, Pearl and Hermes Reef, and Laysan, information on the latter including some information not in Bailey's subsequent publication. Extract also includes observations made in September 1918 by a William Todd at Necker, Nihoa, French Frigate Shoals, Laysan and Kure Atoll, observations made on Laysan in May 1924 by G. P. Wilder, and notes on Laysan from a letter from W. F. Coultas regarding a visit there 15 December 1936.] [POBSP 1560]

Clapp, R. B. 1974. Albinism in the Black Noddy (*Anous tenuirostris*.) Condor 76(4): 464-465. [Specimen taken on Laysan.]

Clapp, R. B. 1980ms. Ornithological observations. Northwestern Hawaiian Islands -- November 1980. Admin. Rep., National Biological Survey, U. S. National Museum, Washington DC. 19 pp. [Observations on Nihoa, French Frigate Shoals, Laysan (16-17 November), Pearl and Hermes Reef and Midway]

Clapp, R. B. 1986. A summary of alcid records from Hawaii. Colonial

Waterbirds 9(1): 104-107. [Provides more information on specimens from Laysan and elsewhere than was available in earlier publications]

Clapp, R. B., and C. A. Ely. 1967ms. Leeward survey No. 21, Preliminary report, Laysan Island. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 14 pp. [Notes and estimates for 26 species of birds and the snake-eyed skink. Table lists 4083 individuals of 15 species banded and 268 recaptures for 13 species (including 28 interisland recaptures for 4 species including 2 Ruddy Turnstones from Alaska.] [POBSP BB 8/SIA 37, 163, 20]

Clapp, R. B., and J. B. Giezentanner. 1980. Tufted Puffin from Laysan - First occurrence in the tropical Pacific. ‘Elepaio 40(9): 120-121. [Remains of *Fratercula corniculata* (USNM 576074) found 13 April 1977 on mud flat at north end of lagoon.]

Clapp, R. B., V. M. Kleen and D. L. Olsen. 1969. First records of Emperor Geese from the Northwestern Hawaiian Islands. ‘Elepaio 30(6): 51-52. [Records from Kure, Midway and Laysan. One Philacte canicagica xx seen on Laysan 27-29 March 1969.] [POBSP 1810]

Clapp, R. B., M. K. Klimkiewicz, and J. H. Kennard. 1982. Longevity records of North American birds: Gaviidae through Alcidae. J. Field Ornithol. 53(2): 81-124. [Longevity records for *Bulweria bulwerii* and *Anas laysanensis*, both banded on Laysan.]

Clapp, R. B. and F. C. Sibley. 1967. New records of birds from the Phoenix and Line Islands. Ibis 109: 122-125.

Clapp, R. B. and P. W. Woodward. 1968. New records of birds from the Hawaiian Leeward Islands. Proc. U.S. Nat. Mus. 124 (No. 3640). 39 Pp. [From Laysan reports the first specimens for Hawaii for Marbled Godwit (*Limosa fedoa*), and Greater Yellowlegs (*Tringa melanoleuca*) as well as first records for Laysan for the Lesser Yellowlegs (*Tringa flavipes*) (sight record), Red-necked Phalaropes (*Phalaropus lobatus*) and the Horned Puffin (*Fratercula corniculata*)(both of the latter from specimens.] [POBSP 1654]

Clark, A. H. 1908. Descriptions of new species of crinoids, chiefly from the collections made by the U. S. Fisheries steamer "Albatross" at the Hawaiian Islands in 1902; with remarks on the classification of the Comatulida. Proc. U.S. Nat. Mus. 34 (No. 1608): 209-244. [Describes two species collected offshore (*Iridometra crispa* (p. 218), *Thalassometra delicata* (p. 225)) by the Albatross Expedition] [POBSP 1576]

Clark, A. H. 1949. Ophiuroidea of the Hawaiian Islands. B.P. Bishop Mus. Bull. 195. 133 pp. [Reports 6 species of brittle stars from collections made by the Albatross Expedition and gives summary lists of other echinoderms previously collected at Laysan] [POBSP 1172]

Clark, H. L. 1912. Notes on the Laysan Finch. Auk 29(2): 166-168. [Notes on morphology of an alcoholic specimen obtained at Laysan by W. K. Fisher] [POBSP 972]

Clark, H. L. 1925. Echinoderms other than sea stars. Pp. 89-111 in Edmondson et al. 1925. Reports 8 brittle-stars (Ophiuroidea), 7 sea-urchins (Echinoidea), and 9 sea-cucumbers (Holothurioidea) collected at Laysan by the Tanager Expedition; describes one brittle-star (*Ophiologimus quadrispinus*) from Laysan as a new species.] [POBSP 1150]

Cochran, C. S. 1910ms. a. Report to the Secretary of the Treasury of a survey of the Hawaiian Bird Reservation in August and September 1910. Rec. Group 26, U.S. Nat. Arch. 2 pp. [All Northwestern Hawaiian Islands were visited with landings being made at Midway, Lisianski, Laysan and French Frigate Shoals. Reports that no evidence was found that the birds had been molested] [POBSP 1547]

Cochran, C. S. 1910ms. b. Report to the Captain Commandant of the Revenue Cutter Service of an inspection of the Hawaiian Bird Reservation in April and May 1912. Rec. Group 26, U.S. Nat. Arch. 2 pp. [Landings made at Laysan (22 April) and at Lisianski (23 April) revealed no signs that the birds had been molested.] [POBSP 1547]

Cochran, C. S. 1913ms a. Report to the Captain Commandant of the Revenue Cutter Service of a cruise to the Hawaiian Bird Reservation in December 1912. Rec. Group 26, U.S. Nat. Arch. 4 pp. [Landings made at French Frigate Shoals, Pearl and Hermes and Laysan, at the latter on 22 and 31 December during which period D. T. Fullaway was collecting insects.] [POBSP 1547]

Cochran, C. S. 1913ms b. Report to the Captain Commandant of the Revenue Cutter Service of a cruise to the Hawaiian Bird Reservation in March 1913. Rec. Group 26, U. S. Natl. Archives. 4 pp. [Landings made at Laysan (11 March), Lisianski (12 March), Midway (14 March) and Pearl and Hermes Reef (15 March), with George Willet swimming ashore at Necker (19 March). 46 Laysan Rails were introduced to Lisianski from Laysan and a pup seal and turtle were taken at Pearl and Hermes Reef.] [POBSP 1547]

Conant, S. 1985ms. Trip Report - Expedition to Laysan Island, 28 February to 14 April 1985. Report to USFWS, Honolulu, HI. [Mostly observations on Laysan Finch, but some also on Laysan Duck and shorebirds]

Conant, S. 1988a. Geographic variation in the Laysan Finch (*Telespiza cantans*). Evol. Ecol. 2(3): 270-282.

Conant, S. 1988b. Saving endangered species by translocation: are we tinkering with evolution? BioScience 38(4): 254-247. [Compares meristics of Laysan Finches

and *Tribulus* mericarps on Laysan and Pearl and Hermes Reef.]

Conant, S., C. C. Christensen, P. Conant, W. C. Gagne' and M. L. Goff. 1984. The unique terrestrial biota of the Northwestern Hawaiian Islands. Pp 77-94 *in* R. W. Grigg and K. Tanoue (eds.). Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands. UNIHI SEAGRANT-MR-84-01. Vol. 1. [Species endemic to the Northwestern Hawaiian Islands include at least 8 land snails, 12 plants, 4 land birds, and more than 50 arthropods. Laysan was reported to have 6 endemic plants, 5 terrestrial molluscs, and 17 endemic terrestrial arthropods, the latter a larger number than any other Northwestern Hawaiian Islands except Nihoa.]

Conant, S., R. C. Fleischer, M. P. Morin, and C. L. Tarr. 1992. When endangered species are aliens: Some thoughts on the conservation of rare species. Pacific Sci. 46(3): 401-402. In: R. H. Cowie (ed.) The impact of alien species on island ecosystems: Extended abstracts of a symposium, 30 May 1991, Honolulu, Hawaii. XVII Pacific Science Congress. [On Laysan Island and translocated Laysan Finch populations].

Coultas, W. F. (ms.). [Notes taken on Laysan Island, 15 December 1936]. Extracts from a letter in the files of the Bureau of Sport Fisheries and Wildlife, Honolulu. 1 p. [Brief notes on 19 species of birds] [POBSP 1560]

Craig, M. P., J. L. Megyesi, C. S. Hall, J. L. Glueck, L. P. Laniawe, E. A. Delaney, S. S. Keefer, M. A. McDermond, M. Schulz, G. L. Nakai, B. L. Becker, L. M. Hiruki, and R. J. Morrow. 1994. The Hawaiian Monk Seal at French Frigate Shoals, 1990-91. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-210. 70 pp. [Data given on populations, reproduction, factors affecting survival, and interatoll movements based on observations made 6-16 May, 13 June-20 August, and 23-29 September 1990 and 24-26 January and 28 March-5 September 1991. Table 16 (p. 44) lists movements of six seals between French Frigate Shoals and Laysan.]

Crossin, R. S. 1965ms a. Island report--July 1965. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 14 pp. [Mostly notes and/or estimates for 21 species of birds; also lists tick incidence for 10 species or birds and returns or sightings of tagged birds for 5 species.] [POBSP BB 8/SIA 37, 163, 14]

Crossin, R. S. 1965ms b. Island report...August 1965. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 16 pp. [Notes and/or estimates for 23 species of birds; also provides data on incidence of ticks on birds, totals banded, band returns, and the results of a Hawaiian Monk Seal census conducted 6 August] [POBSP BB 8/SIA 37, 163, 15]

Crossin, R. S. 1966ms a. Leeward Island survey No. 13, June 1966. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 18 pp. [Largely notes and estimates for 22 species of birds; also provides information on collection of ticks, reptiles, birds, totals for birds banded, and data on band returns and recoveries] [POBSP

BB 8/SIA, 37, 163, 16]

Crossin, R. S. 1966ms b. Notes on the Laysan Finch (*Psittirostra cantans*). Leeward Islands Survey No. 13. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 10 pp. [Observations made in June 1966 of feeding and food, roosting habits, color and plumage, and data on nesting, nest sites, eggs, and young] [POBSP BB 8, SIA 245, Ser. 7, 17, 8]

Crossin, R. S. 1974. The Storm Petrels (Hydrobatidae). Pp. 154-205 *in* W. B. King (ed.). Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zool. 158. [Pelagic range maps and sightings, including waters around Laysan].

Crossin, R. S. and L. N. Huber. 1970. Sooty Tern egg predation by Ruddy Turnstones. Condor 72(3): 372-373. [Cites A. Wetmore (pers. comm.) to the effect that there was heavy predation on Sooty and Gray-backed (*Sterna lunata*) Tern eggs on Laysan in 1923.]

Culliney, J. L. 1988. Islands in a Far Sea. Nature and Man in Hawaii. Sierra Club Books, San Francisco, CA. xiv & 410 pp. [Overview includes all of the Northwestern Hawaiian Islands. A relatively detailed book, it provides a useful synthesis and is more meticulous about citing sources than is true for many of the more general publications.]

Cushman, J. A. 1925. Foraminifera. Pp. 121-144 *in* Edmondson et al. 1925 [Reports 23 species of foraminifera collected just offshore Laysan by the Tanager Expedition; also includes Rhumbler's earlier records, sometimes under new names] [POBSP 1150]

Dall, W. H., P. Bartsch, and H. A. Rehder. 1938. A manual of the recent and fossil pelecypod mollusks of the Hawaiian Islands. B. P. Bishop Mus. Bull. 153: 233 pp. [Lists 10 species of pelecypods collected at or offshore Laysan, most collected by the Tanager Expedition]

Dailey, M. D., R. V. Santangelo, and W. G. Gilmartin. 1988. A coprological survey of helminth parasites of the Hawaiian Monk Seal from the Northwestern Hawaiian Islands. Mar. Mammal Sci. 4(2): 125-131. [Based on samples from Kure (38), French Frigate Shoals (32), Laysan (11) and Lisianski (1)]

Darnell, N. L., and T. O. White. 1993ms. Trip Report: Laysan Island, 01 August 1993 - 14 November 1993. Admin. Rep., USFWS, Honolulu, HI. 16 pp (and 19 unnumbered pp. of appendix material). [Mostly on *Cenchrus* control but also comments provides annotated lists of breeding birds and plants. Provides counts of Laysan duckbn A variety of vagrants are mentioned but with no details on date seen or other descriptive detail.

David, R. E., and J. Hunter. 1994. Laysan Duck population decline. Threatened Waterfowl Res. Group Newsl. No 6: 3-4. [Likely caused by drought, low water level in the lagoon coupled with scarcity of food and outbreak of nematode infection.]

Daws, G. 1988. Hawaii: The Islands of Life. The Nature Conservancy of Hawaii/Signature Publishing Company, Honolulu. 156 pp. [Coffee table book with Laysan briefly mentioned; gives color photographs of several birds and an oblique aerial of the island taken sometime in the 1970s? by G. H. Balazs]

DeLong, R. L. 1967ms. Census and observations of Hawaiian monk seal on Pearl & Hermes Reef, Lisianski, and Laysan Islands, May 31 to June 11, 1967. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 8 pp. [SIA 37, 163, 19]

DeLong, R. 1976ms. Trip report, Hawaiian Islands National Wildlife Refuge, March 17-April 10, 1976. Natl. Mar. Fish. Serv., Seattle, WA. 11 pp, 2 appendices. [Not seen; from Hiruki and Ragen 1992]

Delong, R. 1978. Investigation of Hawaiian Monk Seal mortality at Laysan, Lisianski, French Frigate Shoals, and Necker Island, May 1978. NOAA, NMFS, Northwest and Alaska Fisheries Center Interim Report. 22 pp.

Delong, R., and R. L. Brownell, Jr. 1977. Hawaiian Monk Seal (*Monachus schauinslandi*) habitat and population survey in the Northwestern (Leeward) Hawaiian Islands, April 1977. NOAA, NMFS, Northwest and Alaska Fisheries Center Processed Rep. 43 pp. [Censuses 6-26 April 1977 for Necker, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes, Midway, and Kure.]

Delong, R., C. H. Fiscus, and K. W. Kenyon. 1976. Survey of Monk Seal (*Monachus schauinslandi*) populations of the Northwestern (Leeward) Hawaiian Islands. NMFS, Northwest Fisheries Center Proc. Rep. i + 36 pp. [Observations March-April 1976 of Nihoa, Necker, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes Reef, Kure and Midway. Includes also numbers of Green Turtles (*Chelonia mydas*) seen at different islands, and sightings of various cetaceans (but none at Laysan). Appendix 1, authored by Fiscus alone (pp. 31-43) and entitled "Trip Report: Voyage to Laysan Island, February-March 1977. A part of the joint NMFS-FWS 1977 monk seal (*Monachus schauinslandi*) research program." gives observations of the seal at Laysan and French Frigate Shoals as well as sightings of the turtle at the former.]

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecol. Monogr. 61(2): 115-143. [Laysan Finch treated on p. 136; Figure 10 gives estimated populations derived from transects made between 30 March 1969 and 16 August 1988.]

Dickey, D. R. (ms.). 1995. Notes taken during the Tanager Expedition to the Northwestern Hawaiian Islands. Published in this volume in Atoll Research Bulletin

433.

Diggs, J. T. 1918ms. Report of the cruise of the U. S. S. Hermes among the islands of the Hawaiian Group, 1918. Rec. Group 45, U.S. Nat. Arch. 24 pp. [POBSP 1634] [Observations in September 1918 off Nihoa and Necker and at French Frigate Shoals, Laysan (8 September), Midway (14 September) and Kure. Most of the natural history observations were made on Midway and Laysan. For the latter, 8 pages give an annotated list of birds including brief mention of the Laysan Duck and Laysan Honeyeater (*Himatione sanguinea freethii*), a brief description of conditions on the island, and some notes on rabbits, seals, and turtles.]

Dill, H. R. 1913. The albatross of Laysan. Amer. Mus. J. 13(4): 185-192. [POBSP 551]

Dill, H. R. 1916a. The mating and nesting habits of *Fregata aquila*. Wilson Bull. 28(4): 153-157. [Observations during 1911 visit with 8 black and white photogaphs] [POBSP 1008]

Dill, H. R. 1916b. The albatross of Laysan. Wilson Bull. 28(4): 172-175. [Observations during 1911 visit with 11 black and white photogaphs] [POBSP 1008]

Dill, H. R. 1952a. The University Museum of Natural History: Expedition to Laysan Island. Palimpsest 33(2): 44-52. [Popular account of the 1911 expedition to Laysan with B&W photographs of the ensuing cyclorama at the University of Iowa] [POBSP 1753]

Dill, H. R. 1952b. The University Museum of Natural History: Birds on Laysan Island. Palimpsest 33 (2): 53-64. [Annotated list of birds recorded during the 1911 expedition] [POBSP 1753]

Dill, H. R. and W. A. Bryan. 1912. Report of an expedition to Laysan Island in 1911. U.S. Dept. Agr. Biol. Surv. Bull. 42: 30 pp. [Part I "Report on conditions on the Hawaiian Bird Reservation with list of the birds found on Laysan" is written by Dill and Part II "Report on conditions on Laysan, with recommendations for protecting the Hawaiian Islands Reservation" is written by Bryan. The first part (ca. 3/4 of the report gives the most detailed account of the April-June 1911 survey and many black and white photographs] [POBSP 421]

Dutcher, W. 1905. [Bird protection in the Pacific]. Bird-lore 7(1): 301-306. [POBSP 1096]

Ebasco Environmental. 1993ms. "Dead Zone" site, Laysan Isalnd, Hawaiian Islands National Wildlife Refuge Complex, Honolulu, Hawaii. Draft, Preliminary Assessment/Investigation Summary Report, Task Order 93-003, Contract No. 14-48-0010-93-004. Prepared for U.S. Fish Wildl. Serv., Service Engineering Center,

Lakewood, CO. 28 pp.

Edmondson, C. H. 1925. Crustacea. Pp. 3-62 *in* Edmondson et al. 1925. [Reports 59 species of decapods and a phyllopod from Laysan that were collected on the Tanager Expedition; two decapods (*Crangon laysani*, *Sympagurus pacificus*) from or off Laysan are described as new species.] [POBSP 149, 1150]

Edmondson, C. H., W. K. Fisher, H. L. Clark, A. L. Treadwell, and J. A. Cushman. 1925. Marine zoology of the tropical central Pacific. B. P. Bishop Mus. Bull. 27: ii and 148 pp. [Largely the results of the Tanager Expedition 1923-24. See papers listed under individual authors] [POBSP 1150]

Egler, F. E. 1939. *Santalum ellipticum*, a restatement of Gaudichaud's species. B. P. Bishop Mus. Occ. Pap. 24(20): 349-357. [Places *S. cuneatum* var. *laysanicum* of Laysan in the synonomy of *S. ellipiticum*] [POBSP 303]

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1992. Birds in Jeopardy: The Imperiled and Extinct Birds of the United States and Canada, including Hawaii and Puerto Rico. Stanford Univ. Press. 259 pp. [Treats the extant Laysan Duck (p. 68) and Laysan Finch (p. 75) and the extinct Laysan Rail (p. 202), Laysan Millerbird, *Acrocephalus f. familiaris* (p. 210), and Laysan Honeyeater, *Himatione sanguinea freethi* (p. 213).]

Ego, K., and H. S. H. Yuen. 1976ms. Cruise Report. Townsend Cromwell, cruise 76-04-71. Unpubl. Admin. Rep., Southwest Fish. Center, Honolulu, HI. 8 pp. [Survey on nearshore fishery resources and terrestrial vertebrates of Nihoa, French Frigate Shoals, Laysan and Necker. Minimal information presented.]

Eilerts, B. D. 1984ms. Laysan Island Expedition, November 4-14, 1984. 4 pp. Unpublished report in the files of the U.S. Fish & Wildlife Service, Honolulu, HI. [Includes list of shorebirds seen: Ruff (2), Dunlin (*Calidris alpina*) (1), Sharp-tailed Sandpiper (*C. acuminata*) (11), Pectoral Sandpiper (*C. melanotos*) (1), Bar-tailed Godwit (*Limosa lapponica*) (3), Lesser Yellowlegs (1), Long-billed Dowitcher (*Limnodromus scolopaceus*) (2), Short-billed Dowitcher (*Limnodromus griseus*) (1), Pintail (*Anas acuta*) (9), Green-winged Teal (*Anas crecca*) (5), as well as aerial photograph of island]

Eliason, J. J., T. C. Johanos, and M. A. Webber. 1990. Parturition in the Hawaiian Monk Seal (*Monachus schauinslandi*). Mar. Mamm. Sci. 6(2): 146-151. [Observations at East Island, French Frigate Shoals, 24 April 1985 and at Laysan 28 April; summarizes previous observations in NWH islands, with a previously unpublished observation from Laysan on 5 May 1982.]

Eliot, J. L. 1978. Hawaii's far-flung wildlife paradise. Natl. Geogr. 153(5): 670-691. [Captioned photographs at Laysan include sleeping seal in front of wrecked

Japanese ships, Laysan Duck, egg harvest in 1906 and picture of Tillie Laysan Schlemmer in Honolulu.]

Elschner, C. 1913. Corallogene Phosphat-Inseln Austral-Oceaniens und ihre Produkte. Max Schmidt, Lübeck. 120 pp. Translation of Chapters I and IV in the files of the Pacific Ocean Biological Survey Program, Smithsonian Institution, Washington, D.C. [POBSP 179 - English translation]

Elschner, C. 1915. The leeward islands of the Hawaiian Group [Reprint from Honolulu Advertiser). Honolulu, 69 pp. [Pp. 30-54 deal Elschner's September 1914 visit to Laysan on the *Thetis*. Original material largely deals with physical aspects of the island with other material largely derivative but with some original observations on the vegetation.] [POBSP 461]

Ely, C. A. 1942. Shallow-water Asteroidea and Ophiuroidea of Hawaii. B. P. Bishop Mus. Bull. 176. 63 pp.

Ely, C. A., and R. B. Clapp. 1973. The natural history of Laysan Island, Northwestern Hawaiian Islands. Atoll Res. Bull. 171. xi and 361 pp.

Emerson, W. K., and W. O. Czernohorsky. 1973. The genus *Drupa* in the Indo-Pacific. Indo-Pacific Mollusca 3(13): 1-40. [Records *Drupa ricinus ricinus* (Linnaeus 1758) (p 23) from Johnston Island, and Kure, Midway, Laysan, French Frigate Shoals (Tern Island) in the Northwestern Hawaiian Islands.]

Emery, C. 1899. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1896-1897). Formiciden. Zool. Jahrb., Syst. 12: 438-440. [Describes ant *Ponera punctatissima schauinslandi* subsp nov. and reports three other species (*Monomorium gracillimum*, F. Sm., *Tetramorium guineense* F., *Tapinoma melanocephala* F.) of ants from Laysan.] [POBSP 1760] [POBSP 295, English translation]

Evenhuis, N. L. 1979. Catalog of entomological types in the Bishop Museum. Diptera: Stratiomyidae. Pacific Insects 211): 1-8. [Lists from Laysan the holotype of *Brachycara latifrons* James (p. 4)]

Farrell, A. [ed.]. 1928. John Cameron's Odyssey. The MacMillan Co., New York. 461 pp. [P. 400 has remarks on Laysan Finch and Laysan Rail on Laysan] [POBSP 403]

Fefer, S. I. 1984ms b. Trip Report - Biological Investigations: Nihoa, Necker, Laysan, Lisianski, Pearl and Hermes Reef, Midway, 19 June - 19 July, 1984. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 16 pp.

Fefer, S. I. 1984ms b. Laysan Island Expedition, November 1-9, 1984. Memorandum to U. S. Fish. Wildl. Serv., Honolulu, HI. 7pp. [Includes Laysan Duck

emergency recovery action proposal - FY 85, Hawaiian Islands NWR - Laysan Island]

Fefer, S. I. 1984. Regional Report: Hawaii. Pac. Seabird Group Bull. 9(2): 76-77. [Abstract only. Results of 1980 fieldwork including Laysan briefly described]

Fefer, S. I. 1985ms. Trip Report - NWHI Cruise, 15 May - 13 June 1985. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 12 pp. [Nihoa, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes Reef, and Midway visited. For Laysan, visted 30 May - 3 June, observations were made on vegetation, nesting species, and the Bristle-thighed Curlew (*Numenius tahitiensis*).]

Fefer, S. I. 1985. Regional Report: Hawaii. Pac. Seabird Group Bull. 11(1): 11-13. [Laysan field studies briefly mentioned]

Fefer, S. I., C. S. Harrison, M. B. Naughton, and R. J. Shallenberger. 1984. Synopsis of results of recent seabird research conducted in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. 84-01 (Vol. 1): 9-76. [Population estimates and other remarks on Laysan and the other Northwestern Hawaiian Islands, including Midway. Has much general information on food and feeding habits of birds of the Refuge and addresses present and potential effects of man on seabirds (introductions of predators, exotic insects and plants, habitat alteration, human disturbance, oil pollution and other contaminants.)]

Fefer, S. I., D. Hu, and M. B. Naughton (eds.). Undated ms. Catalog of Hawaiian Seabird Colonies. Refuges and Wildlife, Pacific Islands Office, U. S. Fish and Wildlife Service, Honolulu, HI. 197 pp.

Ferris, G. F. 1927. Fourth report upon Diptera Pupana from the Philippine Islands. Philippine J. Sci. 34: 207-233. [Reports a hippoboscid fly, *Olfersia spinifera* (Leach) from a Wedge-tailed Shearwater (*Puffinus pacificus*) from Laysan] [POBSP 1631]

Fiscus, C. H. 1977. Trip report: Voyage to Laysan Island, February-March 1977. A part of the joint NMFS-FWS 1977 monk seal (*Monachus schauinslandi*) research program. Admin. Rep., 2 May 1977, Natl. Marine Fish. Serv., Honolulu Laboratory. pp. 31-43 (Appendix 1) in Brownell and Delong 1977.

Fiscus, C. H., A. M. Johnson, and K. W. Kenyon. 1978. Hawaiian Monk Seal (*Monachus schauinslandi*) survey of the Northwestern (Leeward) Hawaiian Islands. July 1978. U. S. Dept. Comm., NOAA, NMFS. Northwest & Alaska Fisheries Center Processed Rep., Northwest and Alaska Fisheries Center, Seattle, Washington. ii & 27 pp. [Gives censuses for Nihoa, Necker, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes, Midway and Kure as well as notes on mortality, tagging, and specimens.]

Fisher, H. I., and P. H. Baldwin. 1945. (Untitled). Science (102) 2652: 14. In: Anonymous:Science News. [Reports loss of Laysan Finch and Laysan Rail at Midway

because of military activities.]

Fisher, W. K. 1903. Notes on birds peculiar to Laysan Island, Hawaiian Group. Auk 20(4): 384-397. [Abridged from Fisher 1906a, which was written in 1903; black and white photos include those of the Laysan Rail and Laysan Millerbird at the nest.] [POBSP 975]

Fisher, W. K. 1904a. Home life of a buccaneer. Condor 6(2): 57-61. [Describes display and breeding behavior of Great Frigatebird on Laysan] [POBSP 1178]

Fisher, W. K. 1904b. On the habits of the Laysan Albatross. Auk 21(1): 8-30. [Abridged from Fisher 1903a; copiously illustrated] [POBSP 974]

Fisher, W. K. 1904c. Three boobies interviewed. Condor 6(4): 89-94. [Behavior and habits of Masked Booby (*Sula dactylatra*) and Red-footed Booby on Laysan; 7 black and white photographs] [POBSP 961]

Fisher, W. K. 1904d. Albatross pictures. Condor 6(6): 151-159. [Twelve black and white photographs of Laysan and Black-footed albatrosses with comments on distribution on Laysan, courtship, and food and feeding.]

Fisher, W. K. 1906a. Birds of Laysan Island and the Leeward Islands, Hawaiian group. U.S. Fish. Comm. Bull. 23 (Pt 3): 767-807. [Detailed systematic and ecological account of the birds, with notes on geography and vegetation, list of plants, many excellent photographs] [POBSP 1338]

Fisher, W. K. 1906b. The starfishes of the Hawaiian Islands. U.S. Fish. Comm. Bull. 23 (pt. 3): 987-1130. [Reports six species, most newly described, from collections made offshore by the Albatross Expedition] [POBSP 1567]

Fisher, W. K. 1907. The holothurians of the Hawaiian Islands. Proc. U.S. Nat. Mus. 32 (No. 1555): 637-744. [Reports six species from collections made by the Albatross Expedition] [POBSP 1561]

Fisher, W. K. 1925. Sea stars. Pp. 63-87 *in* Edmondson et al. 1925. [Report three species of starfish collected at Laysan by the Tanager Expedition: *Linckia guildingii* Gray, *Mithrodia bradleyi* Verrill, and one described as a new subspecies, *Dactylosaster cylindricus pacificus*]

Fisher, W. K. 1952. The siphunculid worms of California and Baja California. Proc. U. S. Natl. Mus. 102(3306): 371-450. [Reports *Phascolosoma dentigerum* from Laysan.]

Fleischer, R. C., S. Conant, and M. P. Morin. 1991. Genetic variation in native and translocated populations of the Laysan Finch (*Telespiza cantans*). Heredity 66(1):

125-130. [Comparison of Laysan population with that introduced on Pearl and Hermes Reef.]

Fleet, R. R. 1964ms. Leewards Islands survey No. 5, September 1964. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 10 pp. [SIA 37, 163, 10]

Flint, B. (comp.) 1995. Laysan Island, HI. [Christmas Count]. Natl. Audubon Soc. Field Notes 49(4): 837. [374449 individuals of 25 species counted on 21 December 1994. Less common species recorded included 7 Cattle Egrets, 1 Green-winged Teal, 55 Northern Pintails, 4 Long-billed Dowitchers, and 1 Glaucous-winged Gull.]

Fosberg, F. R. 1962. Miscellaneous notes on Hawaiian plants -- 3. B. P. Bishop Mus. Occ. Papers 23 (2): 29-44. [Includes reference *Santalum ellipticum* Gaudichaud on Laysan] [POBSP 211]

Fosberg, F. R., and D. Herbst. 1975. Rare and Endangered species of Hawaiian vascular plants. Allertonia 1(1): 1-72. [Lists all endangered species in Hawaii & their status, including Laysan endemics such as *Sicyos laysanensis*, *S. semitonsus*, *S. maximowiczii*]

Fowler, H. W. 1927. Fishes of the tropical central Pacific. B. P. Bishop Mus. Bull. 38: 32 pp. [Lists seven species from Laysan, six from the Tanager collections including one unreported by Fowler 1925 and one from a collection in May 1893] [POBSP 1250]

Fowler, H. W. 1928. The fishes of Oceania. B. P. Bishop Mus. Mem. 10, 540 pp. [Gives distributional records of the fish fauna as then known; includes Laysan.] [POBSP 1253]

Fowler, H. W. 1934. The fishes of Oceania-Supplement 2. B.P. Bishop Mus. Memoir 11 (6): 385-466. [Gives new distributional records for two species at Laysan from collection made in August 1930] [POBSP 1253]

Fowler, H. W., and S. C. Ball. 1924. Descriptions of new fishes obtained by the Tanager Expedition of 1923 in the Pacific Islands west of Hawaii. Proc. Acad. Nat. Sci. Phila. 76: 269-274. [Describes *Gregoryina gygis* as a new family, genus and species of a fish collected from a White Tern's nest at Laysan by the Tanager Expedition] [POBSP 1572]

Fowler, H. W., and S. C. Ball. 1925. Fishes of Hawaii, Johnston Island, and Wake Island. B.P. Bishop Mus. Bull. 26: 31 pp. [Reports 71 species of fish collected at Laysan by the Tanager Expedition] [POBSP 1193]

Freed, L. A., S. Conant, and R. C. Fleischer. 1987. Evolutionary ecology and radiation of Hawaiian passerine birds. Trends in Ecol. Evol. 2(7): 196-203. [Diet of Laysan Finch is discussed.]

Frings, H., M. Frings, and C. Frings. 1966. An annotated bibliography on North Pacific albatrosses. Pacific Sci. 20(3): 312-337.

Froescher, R. C. 1976. The burrowing bugs of Hawaii, with description of a new species (Hemiptera: Cydnidae.). Proc. Haw. Entomol. Soc. 22(2): 229-235. [*Geotomus pygmaeus* sp. nov. from Nihoa, Midway, Pearl and Hermes, Midway, and Laysan.]

Frohawk, F. W. 1892. Description of a new species of rail from Laysan Island (North Pacific). Ann. Mag. Nat. Hist. III, 9(6): 247-249. [Laysan Rail (*Porzanula palmeri*), now known as *Porzana palmeri*.][POBSP 333]

Fullaway, D. T. 1914a. A new species of *Oodemas* from Laysan Island. Proc. Haw. Entomol. Soc. 3(1): 18. [Beetle, *Oedemas laysanensis*, described from material collected in April 1911 and in December 1912]

Fullaway, D. T. 1914b. A list of Laysan Island insects. Proc. Haw. Entomol. Soc. 3(1): 20-22. [Lists 60 species from Laysan from collections made in 1905 by Wilder (6 species), 1911 by Bryan (3), and 1912 by Fullaway (55).] [POBSP 1363]

Fullaway, D. T. 1923. How coming of man affects the isles of Leeward Hawaii. Honolulu Advertiser, May 27, 1923. Four pictures. [Not seen. Observations during Tanager Expedition on Kure, Midway, Pearl and Hermes Reef and Laysan. From Bryan 1978]

Furman, D. P., and M. D. Dailey. 1980. The genus *Halarachne* (Acari: Halarachinidae), with the description of a new species from the Hawaiian Monk Seal. J. Med. Entomol. 17(4): 352-359. [*Halarachne laysanae* sp. nov. described from Laysan.]

Gagne, W. C. 1984ms. Trip-report: Biological investigations of Laysan's hypersaline lake and related aspects. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 17 pp. [First report to mention *Scaevola* dieback which is affecting seabirds. Also reports on guano samples checked for presence of *Pisonia*, and gives life history of brine flies, an important food of Laysan Duck.]

Garrett, L. E., and F. H. Haramoto. 1967. A catalog of Hawaiian Acarina. Proc. Haw. Entomol. Soc. 19(3): 381-414. [Summarizes earlier records from nine Northwestern Hawaiian Islands including Laysan.] [POBSP 1579]

Gauger, V. 1995. Successive clutches in the Black Noddy, *Anous minutus*. Pacific Seabirds 22(1): 31. [Abstract of work done on Tern (1987-89) and Laysan (1993-1994)

islands.]

Gerrish, G., and K. W. Bridges. 1979. Botanical summary of the terrestrial ecosystems of the Hawaiian Islands, American Samoa, and the U.S. Trust Territory of the Pacific Islands. In: Byrne, J.E. (ed.) 1979 (see separate citation). [Chapter on leeward islands, lists endangered plants of Laysan, pp 2-12-13), pp. 1-30.]

Gerrodette, T. 1985. Estimating the 1983 population of Hawaiian Monk Seals from beach counts. NMFS/SWFC Admin. Rep. H-85-5. 13 pp. [Most of the field test of the method was done on Lisianski but a table on p. 9 uses the method to modify estimates for all islands censused, including Laysan during 1983.]

Gerrodette, T., B. K. Choy, and L. M. Hiruki. 1990. An experimental study of derelict gill net fragments in the central Pacific Ocean. Pp. 600-614 *in* R. S. Shomura and M. L. Godfrey (eds.). Proc. Second Internatl. Conf. Marine Debris, 2-7 April 1989. NOAA Tech. Mem. NMFS 154. FR 38(2)

Giezentanner, J. B. 1977ms a. Expedition Report. Hawaiian Islands National Wildlife Refuge. February 17 - March 6, 1977. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu, HI. 13 pp. [Survey of French Frigate Shoals and Laysan, the latter visited 28 February - 2 March. Gives population estimates and brief notes on birdlife as well as notes on seals and turtles.]

Giezentanner, J. B. 1978ms. Trip Report, Hawaiian Islands National Wildlife Reserve, April 6-26, 1977. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu, HI. 8 pp. [Not seen; from Hiruki and Ragen 1992]

Giezentanner, J. B., D. Woodside, J. Sincock, and E. Kridler. 1982. Laysan Duck recovery plan. U.S. Fish Wildl. Serv., Portland, Oregon.

Gilbert, C. H. 1905. The deep-sea fishes of the Hawaiian Islands. U.S. Fish. Comm. Bull. 23 (pt. 2): iii-xi and 575-713. [Records 24 species of deep sea fishes collected in the vicinity of Laysan by the Albatross Expedition and describes one species *Grammatonotus laysanus*, collected at Laysan by Max Schlemmer] [POBSP 1641]

Gilbert, B. 1971. Then came man and a mustard seed. Sports Ill. 35(11): 96-109. [Not seen; from Mill et al. 1988]

Gill, L. T. 1930. Dwellers on the reefs. Birds of the Northwestern Hawaiian Islands. Nature Mag. 15: 237-240. (April) [Popular account of Tanager Expedition; largely on Laysan but also with two photographs of birds on Nihoa and Necker.]

Gill, R. E., and C. M. Handel. 1990. Summary of the proceedings from the workshop on Bristle-thighed Curlews, Anchorage, Alaska. 22 pp.

Gilmartin, W. G. 1981. Hawaiian Monk Seal recovery uncertain. Seal Report, pp. 3,6. Publ. Center Environ. Education, Washington, D.C.

Gilmartin, W. G. 1983. Recovery plan for the Hawaiian Monk Seal (*Monachus schauinslandi*). NOAA, NMFS, Southwest Region. 44 pp. [Summary of observations in the Northwestern Hawaiian Islands including some previously unpublished observations from Laysan.)

Gilmartin, W. G. 1987. Hawaiian Monk Seal die-off response plan, a workshop report. Southwest. Fish. Cent. Honolulu Lab., NMFS, NOAA, Honolulu, HI. Admin. Rep. H-87-19. 7 pp.

Gilmartin, W. G. 1988. The Hawaiian Monk Seal: population status and current research activities. NOAA, NMFS, SWFC Admin. Rep. H-88-17. 14 pp. [Laysan mentioned frequently; table gives number of seal births per year on each of the islands (where known) from 1977 to 1987.]

Gilmartin, W. G. 1990. Hawaiian Monk Seal Work Plan, Fiscal Years 1991-93. Southwest. Fish. Sci. Cent., Admin. Rep. H-90-14. 43 pp. [Mention of all monk seal sites]

Gilmartin, W. G. 1993. Hawaiian Monk Seal Work Plan, Fiscal Years 1994-96. Southwest. Fish. Sci. Cent., Admin. Rep. H-93-16. 83 pp. [Mention of all monk seal sites]

Gilmartin, W. G., and D. J. Alcorn. 1987. A plan to address the Hawaiian Monk Seal adult male "mobbing" problem. Southwest Fisheries Center Admin. Rep. H-87-12. 24 pp. [Directed to problem of males killing females and immature seals at Laysan]

Gilmartin, W. G., R. L. DeLong, W. A. Smith, L. A. Griner, and M. D. Dailey. 1980. An investigation into unusual mortality in the Hawaiian Monk Seal, *Monachus schauinslandi*. Pp. 32-41 *in* R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigation in the Northwestern Hawaiian Islands. Univ. Hawaii Seagrant Misc. Rep. UNIHI-Seagrant-MR-80-04. [1978 observations from dead animals from Laysan and a smaller number from French Frigate Shoals]

Gilmartin, W. G., and L. L. Eberhardt. 1995. Status of the Hawaiian Monk Seal (*Monachus schauinslandi*) population. Can. J. Zool. 73(6): 1185-1190. [Summarizes population trends and factors affecting survival on Northwestern Hawaiian Islands. Graphs population trends 1956-1992 for Kure, Midway, Pearl and Hermes, Lisianski, French Frigate Shoals and Laysan. At Laysan the overall trend has been consistently downward since the mid-1960's.]

Gilmartin, W. G., T. C. Johanos, and L. L. Eberhardt. 1993. Survival rates for the Hawaiian Monk Seal (*Monachus schauinslandi*). Mar. Mamm. Sci. 9(4): 407-420.

[Based on pups tagged since the early 1980's at Kure, Pearl and Hermes Reef, Lisianski, Laysan and French Frigate Shoals. Survival rates on animals up to one year old ranged from 0.80 to 0.90 and for young seals 0.85 to 0.98. Higher number of tagged pups at Laysan and Lisianski allowed separate estimates for males and females with immature females surviving better than males.]

Gilmartin, W. G., T. C. Johanos, and T. Gerrodette. 1987. Preliminary assessment of juvenile Hawaiian Monk Seal survival. Southwest Fish. Center Honolulu Lab., Honolulu, HI. Southwest Fisheries Center Admin. Rep. H-87-16. 11 pp. [Summarizes data obtained on Laysan 1983-1986 with information also for Kure, Pearl and Hermes Reef, Lisianski Island, and French Frigate Shoals.]

Goff, M. L. 1971. New records of chiggers (Acarina, Trombiculidae) from the Northwestern Hawaiian Islands. J. Med. Entomol. 8(4): 456. [Three species from Pearl and Hermes and one, *Neoschoengastia gallinarum* (Hatori) from a Golden Plover on Laysan.]

Goff, M. L. 1987. A catalog of Acari of the Hawaiian Islands. Coll. Trop. Agric. and Human Resour., Univ. of Hawaii Research Extension Service 075: 1-75. [Catalog lists all previously known records from Laysan. Contains one new record (*Bdellodes longirostris*) from Laysan, many from the main islands, and some from Kure, Midway, Pearl and Hermes Reef, and Nihoa.]

Gould, P. J. 1974. Sooty Tern (*Sterna fuscata*). Pp. 6-45 *in* W. B. King (ed.), Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zool., No. 158. [Pelagic range maps and sightings, including waters around Laysan.]

Gould, P. J., W. B. King and Gerald A. Sanger. 1974. Red-tailed Tropicbird (*Phaethon rubricauda*). Pp. 206-231 *in* W. B. King, (ed.), Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zool., No. 158. [Pelagic range maps and sightings, including waters around Laysan].

Grant, C. 1947. Frigate birds and the Laysan Rail. Condor 49(3): 130. [Mentions bringing a few rails from Wake Island to Laysan in 1923, all of which subsequently were found dead along the lagoon] [POBSP 965]

Greaney, E. 1959. Honolulu Advertiser October 6, 7, 8. [Not seen. Said to contain three columns on the Pacific Guano and Fertilizer Company and guano from Midway, Laysan, Jarvis and other islands (Bryan 1978)]

Greenway, J. C., Jr. 1958. Extinct and vanishing birds of the world. Amer. Committee Internatl. Wildlife Protection. Special Publ. 13, New York. x and 518 pp.

Gregory, H. E. 1924. Report of the Director for 1923. B. P. Bishop Mus. Bull.

10: 38 pp. [POBSP 184]

Gregory, H. E. 1925. Report of the Director for 1924. B. P. Bishop Mus. Bull. 21: 55 pp. [Contains preliminary reports of the Tanager, Whippoorwill, and Kaimaloa expedtions with original information on central Pacific atolls] [POBSP 218]

Gregory, H. E. 1931. Report of the Director for 1930. B. P. Bishop Mus. Bull. 82: 36 pp. [POBSP 1691]

Griffin, C. R., R. J. Shallenberger, and S. I. Fefer. 1989. Hawaii's endangered waterbirds. A resource management challenge. Pp. 155-169 *in* R. R. Sharitz and J. W. Gibbons (eds.). Proc. of freshwater wetlands and wildlife symposium. Savannah River Ecol. Lab., Aiken, Georgia.

Grigg, R. W. 1981a. *Acropora* in Hawaii. Part 1. History of the scientific record, systematics, and ecology. Pacific Sci. 35(1): 1-13. [Figure 4 shows distribution of three species of *Acropora* including records in the Northwestern Hawaiian Islands for Nihoa, French Frigate Shoals, Gardner Pinnacles, Maro Reef, and Laysan from surveys conducted in 1979 at these and other Northwestern Hawaiian Islands. Only *A. cytherea* was found at Laysan where it is rare.]

Grigg, R. W. 1981b. *Acropora* in Hawaii. Part 2. Zoogeography. Pacific Sci. 35(1): 15-24. [p. 17 mentions that only two colonies of *A. cytherea* have been found at Laysan in 30,000 square meters of reef surveyed. Laysan and other Northwestern Hawaiian Islands mentioned several other places.]

Grigg, R. W. 1981c. Coral reef development at high latitudes in Hawaii. Pp. 687-693 in E. D. Gomez, C. E. Birkeland,, R. W. Buddemeier, R. E. Johannes, J. A. Marsh, Jr., and R. T. Tsuda (eds.). The Reef and Man. Proc. Fourth Internatl. Coral Reef Sympsosium, Manila, Vol. 1. [Mentions both main and all the Northwestern Hawaiian Islands including Laysan]

Grigg, R. W. 1982. Darwin Point, a threshold for atoll formation. Coral Reefs 1: 29-34. [Includes observations for all the Northwestern Hawaiian Islands, including Laysan.]

Grigg, R. W. 1983. Community structure, succession and development of coral reefs in Hawaii. Mar. Ecol. Progr. Ser. 11: 1-14. [Deals with most of the main and all the Northwestern Hawaiian Islands listing hermatypic corals found on transects of each.]

Grigg, R. W., and S. J. Dollar. 1980. The status of reef studies in the Hawaiian Archipelago. Pp. 100-120 *in* R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. UNIHI-Seagrant-MR-80-04. [Miscellaneous aspects of coral reef in the

main islands and Nihoa, Necker, Gardner Pinnacles, French Frigate Shoals, Maro Reef, Laysan, Lisianski, Pearl and Hermes Reef, Midway and Kure.]

Grigg, R. W., and R. T. Pfund (eds). 1980. Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands. Sea Grant Misc. Rep. UHIHI-Seagrant-MR-80-04. 333 pp. [See papers by Balazs; Gilmartin, Delong, Smith, Griner, and Dailey; Grigg and Dollar; Harrison and Hida; Hirota, Taguchi, Shuman and Jahn; Hobson; Ito and Uchida; Okamoto and Kawamoto; Uchida, Uchiyama, Humphreys and Tagami; Uchida, Uchiyama, Tagami and Shiota; and Uchiyama for references to Laysan.]

Grigg, R. W., and K. Y. Tanoue (eds.). 1984. Proceedings of the Second Symposium of Resource Investigations in the Northwestern Hawaiian Islands. 2 vols. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-01. [See papers by Balazs et al., Conant et al., Fefer et al., Henderson and Gilmartin, Okamoto and Keneka, Uchida and Tagami, Uchiyama and Tagami, and Withers in Vol. 1 for mention of Laysan.]

Gurney, A. B. 1972. Some early records by J. D. Alfken of insects from Hawaii and Laysan. Proc. Haw. Entomol. Soc. 21 (2): 223-224. [Unimportant. Only a reference to Alfken's earlier paper]

Haas, G. E., N. Wilson, and P. Q. Tomich. 1972. Ectoparasites of the Hawaiian Islands, I. Siphonaptera. Contrib. Amer. Entomol. Inst. 8(5): 1-76. [*Parapsyllus laysanensis* Wilson n. sp. is described from Laysan Albatross nest material from Laysan 8 December 1963; other specimens were obtained from Wedge-tailed Shearwater nests the following day.]

Hackman, C. D. 1967ms. Preliminary report of Leeward Island survey No. 18, March 6 to March 27, 1967. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 12 pp. [SIA 37, 163, 18]

Haight, W. R., and J. J. Polovina. 1992. Status of lobster stocks in the Northwestern Hawaiian Islands, 1991. Southwest Fish. Sci. Cent. Admin. Rep., Honolulu, H-92-02. 33 pp. [Reports results of research trapping conducted at Laysan Island, Maro Reef, and Necker Island by personel aboard the *Townsend Cromwell* during a survey from 24 June to 21 July 1991. Laysan is mentioned on p. 2 and in Figure 3 (p. 13) which shows spiny lobster (*Panulirus marginatus*) catch per unit effort there in 1977, 1985-86, and in 1991.]

Hardwick, D. F. 1965. The corn earworm complex. Mem. Entomol. Soc. Canada 40: 247 pp. [Discusses specimens of *Heliocoverpa* (Noctuidae) collected in September 1961]

Hardy, D. E. 1960. Insects of Hawaii. Vol. 10. Diptera: Nematocera - Brachyura.

E.C. Zimmerman, Ed. Univ. of Hawaii Press, Honolulu. vii and 368 pp. [Describes stratiomyid fly, *Brachycera latifrons* from Laysan from specimens collected by the Tanager Expedition] [POBSP 1617]

Hardy, D. E. 1964. Insects of Hawaii. Vol. 11. Diptera: Brachycera II - Cyclorrhapha l. E.C. Zimmerman, Ed. Univ. of Hawaii Press, Honolulu. vii and 458 pp. [Lists 2 dolichopodid flies from Laysan] [POBSP 1616]

Hardy, D. E., and M. D. Delfinado. 1980. Insects of Hawaii. Vol. 13. Diptera: Cyclorrhapha III, Series Schizophora Section Acalypterae, exclusive of Family Drosophilidae. Univ. Hawaii Press, Honolulu. vii + 451 pp. [Lists records from all Northwestern Hawaiian Islands with 8 species listed or implied for Laysan] *Leptocera* (*Poecilosomella*) *punctipennis* (Wiedemann) [Relisting of specimen collected by Fullaway 8 April 1923], *Copromyza* (*Rachispoda*) *downesi* Richards ["Also collected on Laysan..."], *Copromyza* (*Thoracochaeta*) *brachystoma* (Stenhammar)["Lisiansky, Laysan and Midway Islands"], *Bryania bipunctata* Aldrich, ["Northwestern Hawaiian Islands, Layson and Kure Islands (Hardy, 1967:326)"; type locality Nihoa Island], *Neoscatella sexnotata* (Crisson)["Nihoa, Necker, and Laysan), and Wake Island."; occurs in the lagoon at Laysan where it is apparently quite common (p.347], *Milichiella lacteipennis* (Loew)["Common on all the Hawaiian Islands, including Kure, Laysan, Midway, Pearl and Hermes Reef, and probably other Leeward Islands."], *Canaceoides angulatus* Wirth [...Laysan Island, Lisianski Island, Wake Island, Midway Atoll..."], *Siphunculina striolata* (Wiedemann)["First reported on the Leeward Hawaiian Islands and Oahu by Bryan (1931:335)"]

Hardy, D. E. 1981. Insects of Hawaii. Volume 14. Diptera: Cyclorrhapha IV, Series Schizophora, Section Calyptratae. Univ. Hawaii Press, Honolulu. i-vi + 491 pp. [Lists species from all the Northewestern Hawaiian Islands but only two specifically from Laysan both of which had been reported previously: [*Olfersia aenescens* Thomson (pp. 22-23), and *Lucilia graphita* Shannon (p. 349).]

Harrison, C. 1980ms. Trip report, R/V Townsend Cromwell Cruise, 28 May-28 June 1980. NMFS, Southwest Fish. Center Honolulu Lab. 4 pp. [Not seen; from Hiruki and Ragen 1992]

Harrison, C. 1980. Regional Report: Central Pacific. Pac. Seabird Group Bull. 7(1): 18-19. [Laysan field studies briefly described]

Harrison, C. 1981. Regional Report: Hawaii. Pac. Seabird Group Bull. 8(1): 16-17. [Laysan field studies briefly described]

Harrison, C. S. 1990. Seabirds of Hawaii. Natural History and Conservation. Cornell Univ. Press, Ithaca, NY. 249 pp. [Frequent mention of Laysan.]

Harrison, C. S., T. S. Hida. and M. P. Seki. 1983. Hawaiian seabird feeding

ecology. Wildl. Monogr. 85: 71 pp. [Frequent mention of Laysan which was one of the major localities from which food samples were obtained; also lists populations estimates for all islands that are derivative for all but Midway.]

Harrison, C.S., and T. S. Hida. 1980. The Status of Seabird Research in the Northwestern Hawaiian Islands. Pp. 17-31 *in* R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigation in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. UNIHI-Seagrant- MR-80-04 [Much work done at Laysan]

Harrison, C. S., M. B. Naughton, and S. I. Fefer. 1984. The status and conservation of seabirds in the Hawaiian Archipelago and Johnston Atoll. ICBP Tech. Publ. 2: 513-526. [Population estimates for Laysan, etc.]

Harry, R. R. 1953. Skin diving on a Polynesian expedition. Skin Diver 2(3): 6-7. [Notes on 1951 Vanderbilt expedition to Laysan and Midway.] [POBSP 480]

Hartert, E. 1919-1927. Types of birds in the Tring Museum. Novit. Zool. 26: 123-178, 32: 259-276, 33: 344-357, 34: 1-38. [These parts of the enumeration include mentions of atoll birds, especially those from Laysan.] [POBSP 357]

Hartlaub, C. 1901. Hydroiden aus dem Stillen Ocean. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1897-97). Zool. Jahrb., Syst. 14: 349-379. [Reports *Plumularia* (*Halopteris*) *buski* Bale from Laysan] [POBSP 1591]

Hartlaub, G. 1893. Vier seltene Rallen. [Four rare rails] Abhdl. d. Naturw., Bremen. 12: 389-402. [Laysan Rail, *Porzanula palmeri*, described] [POBSP 1227]

Hartman, O. 1966. Polychaetous annelids of the Hawaiian Islands. B. P. Bishop Mus. Occ. Papers 23(11): 163-252. [Summarizes earlier reports from Laysan and gives current taxonomy] [POBSP 1587]

Hebard, M. 1926. Dermaptera and Orthoptera. Pp. 82-88 *in* E. H. Bryan, Jr. et al. 1926. [Lists 2 species of earwigs from Laysan from specimens collected there in 1923]

Heller, A. A. 1897. Observations on the ferns and flowering plants of the Hawaiian Islands. Minnesota Botanical Studies 1: 760-922. [On pp. 760-761 is a brief remark about Laysan reporting two plants, one of which, *Gossypium tomentosum*, does not occur there.] [POBSP 484]

Henderson, J. R. 1985. A review of Hawaiian Monk Seal entanglements in marine debris. Pp. 326-335 *in* R. S. Shomura and H. O. Yoshida, (eds.) Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii. NOAA Tech. Memo. NMFS SWFC-54. [Secondary mention of entangled seals at Laysan citing Alcorn 1984. Also mentions that no scarred or entangled seals

had been seen at Laysan since then (1982). Much data from French Frigate Shoals, and lesser amounts from Lisianski, Kure and Midway with some new information largely personal communications.]

Henderson, J. R. 1988. Marine debris in Hawaii. Pp. 189-206 *in* B. L. Alverson and J. A. June (eds.). Proceedings of the North Pacific Rim Fishermens's Conference on Marine Debris, 13-16 October 1987, Kailua-Kona, Hawaii. [Mention is made (p. 196) of Laysan Finches drowning in a plastic cooler in 1986; other examples of debris and its effects are also given for various organisms at French Frigate Shoals, Lisianski, Nihoa, and Pearl and Hermes Reef.]

Henderson, J. R. 1990. Recent entanglements of Hawaiian Monk Seals in marine debris. Pp, 540-553 *in* R. S. Shomura and M. L. Godfrey, (eds.) Proceedings of the second In!ernational Conference on Marine Debris, April 2-7 1989, Honolulu, Hawaii. U. S. Dept. Comm. NOAA Tech. Memo. NMFS SWFC-154. [34 entanglements recorded 1985-88 with detailed records given for Kure, French Frigate Shoals, Lisianski, and Laysan, with much of the data previously unpublished. Rates were highest at Lisianski, lowest at French Frigate Shoals.]

Henderson, J. R., S. L. Austin, and M. B. Pillos. 1987. Summary of webbing and net fragments found on Northwestern Hawaiian Islands beaches, 1982-86. Southwest. Fish. Cent. Honolulu Lab., NMFS, NOAA, Honolulu HI. SWFC Admin. Rep. H-87-11. 15 pp. [Number of nets and net fragments, annual acculation of nets, locations of nets for Lisianski, Laysan, French Frigate Shoals, Pearl and Hermes Reef and Kure.]

Henderson, J. R., and W. G. Gilmartin. 1984. The Hawaiian Monk Seal: A synopsis of research. Pp. 95-96 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-01. Vol. 1. [Abstract only]

Henshaw, H. W. 1900-1902. Complete list of the birds of the Hawaiian possessions, with notes on their habits. Hawaiian Almanac and Annual for 1902. pp. 54-106, Hawaiian Almanac and Annual for 1903. pp. 76-117, Hawaiian Almanac and Annual for 1904, pp. 113-145. T. G. Thrum, Honolulu, HI. [Mention of birds on Laysan is wholly derivative being based on the works of Rothschild and Schauinsland. Species listed as occurring on Laysan are in Part 1 on p 82 (*Acrocephalus familiaris*), and p 106 (*Himatione freethii*); in Part 2 on p 83 (*Telespiza cantans*), p 107 (*Limosa lapponica*), p 108-109 (*Tringa acuminata*), *Crymophilus fulicarius*, p 113 (*Porzana palmeri*); in part 3 on p 119-124 (*Anas americana*, *Anas boschas* (= *A. platyrhynchos*), *Anas carolinensis*, *Anas laysanensis*, *Fregata aquila* = *minor*, *Phalacrocorax pelagicus*, *Sula cyanops* (= *dactylatra*), *S. piscator* (= *sula*), p. 126-133 (*Phaethon rubricauda*, *Puffinus cuneatus* (= *pacificus*), *Puffinus nativitatis*, *Oceanodroma fuliginosa* (= *tristrami*), *Bulweria bulweri*, *Aestrelata hypoleuca* (= *Pterodroma hypoleuca)*, *Diomedea immutabilis*, *Sterna fuliginosa* (= *fuscata*); p 135-136 (*Anous stolidus*, *Gygis alba*, *Larus glaucescens*).

Henshaw, H. W. 1902. Birds of the Hawaiian Islands, being a complete list of the birds of the Hawaiian possessions with notes on their habits. Honolulu, HI, T. G. Thrum. 146 pp. [Identical to the above with the exception of a few paragraphs in the introduction. In addition to 1900-1902 work are included a table (pp. 137-140) listing occurrence of 125 species by island, the terminal column being headed "Laysan or the other "Bird Isls"" and an index to various species covered.] [POBSP 1028]

Henshaw, H. W. 1912. Our mid-Pacific bird reservation. Yearbook U.S. Dept. Agri. 1911: 155-164. [POBSP 141]

Henshaw, H. W. 1913. Report of the Chief. In: in U. S. Biological Survey, Annual Report, U.S. Dept. Agriculture 1913: 10-11. ["Expedition to Laysan Island"]

Henshaw, H. W. 1915. Report of the Chief. U.S. Biological Survey, Annual Report, Department of Agriculture, 1915: 15 pp. [On pp 9-10 is given a short account of the 18 March - 3 April trip of the USCGC Thetis to the Northwestern Hawaiian Islands with the discovery of substanting feather poaching on Laysan.]

Henshaw, H. W. 1918. A mid-Pacific bird reservation. Mid-Pacific Magazine 15(3): 282-285. [Includes short description of Laysan, with notes on vegetation and birds. Essentially a rehash of the 1912 report] [POBSP 194]

Herald, E. S. 1952. "Pioneer" in the Pacific. Pacific Discovery 5(5): 15-17. [Laysan visited by the George Vanderbilt Pacific Equatorial Expedition of 1951. States that about 120 species of fish were collected and has 4 B&W photos of the birds and seal at Laysan]

Herbst, D. R. 1980. Miscellaneous notes on the Hawaiian flora. I. Phytologia 45(1): 67-81. [Additional floral records from Nihoa, Necker, French Frigate Shoals and Laysan. For Laysan, visited 3-14 September 1968, gives records for *Cenchrus echinatus* L. and *Chenopodium oahuense* (Meyen) Aellen.]

Herbst, D. R. 1983ms. Checklist of the vascular plants of the Northwestern Hawaiian Islands. [Available from the U.S. Fish and Wildlife Sevice, Endangered Species Office, Honolulu, HI; not seen, from Newman 1988.]

Herbst, D. R., and W. L. Wagner. 1992. Alien plants on the Northwestern Hawaiian Islands. Pp. 189-224 in C. P. Stone, C. W. Smith, and T. Tunison (eds.). Alien plant invasions in native ecosystems of Hawaii: management and research. CP5U/UH, Dept. of Botany, Univ. of Hawaii, Honolulu, Hawaii [Complete listing for all the Northwestern Hawaiian Islands including Laysan. Much is derivative but some might represent original observations by Herbst.]

Hincks, W. D. 1938. The Dermaptera of Oceania. J. Feder. Malay St. Mus. 18: 299-310. [A list with bibliography; includes various records from atolls, among them

Laysan. The records are derivative and based on Fullaway (1914).] [POBSP 506]

Hirota, J., S. Taguchi, R. F. Shuman, and A. E. Jahn. 1980. Distribution of plankton stocks, productivity and potential fishery yield in Hawaiian waters. Pp. 191-203 *in* R. W. Grigg and R. T. Pfund. (eds.). Proc. Symposium on Status of Resource Investigation in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. UNIHI-Seagrant-MR-80-04. [One of the transects sampled inshore waters near Laysan.]

Hiruki, L. M. 1991. The significance of wounding to the survival of the Hawaiian Monk Seal, (*Monachus schauinslandi*). M. S. thesis, Univ. Alberta, Edmonton, Canada, 110 pp.

Hiruki, L. M., W. G. Gilmartin, B. L. Becker, and I. Stirling. 1993. Wounding in Hawaiian Monk Seals (*Monachus schauinlandi*). Can. J. Zool. 71(3): 458-468. [Observations at Laysan and French Frigate Shoals in 1988 and 1990.]

Hiruki, L. M. and T. J. Ragen. 1992. A compilation of historical Hawaiian monk seal (*Monachus schauinslandi*) counts. U. S. Dep. Comm., NOAA Tech. Memo. NMFS-SWFSC-172. 200 pp. [Detailed tabular listing of all counts and estimates from the Northwestern Hawaiian Islands, island by island, from the 1800's to 1980-81 with 157 numbered references to published and unpublished sources. Appendix F, pp. 101-123, deals with Laysan presenting data from 24 March 1828 to 17 June 1981. Some errors exist in references, e.g. data for 1915, 1923, and 1936 should be reference 32 not 23.]

Hiruki, L. M., I. Stirling, W. G. Gilmartin, T. C. Johanos, and B. L. Becker. 1993. Significance of wounding to female reproductive success in Hawaiian Monk Seals (*Monachus schauinslandi*) at Laysan Island. Can. J. Zool. 71(3): 469-474. [87.5% of adult females that died on Laysan 1983-89 sustained injuries from adult males.]

Hobson, E. S 1980. The structure of reef fish communities in the Hawaiian Archipelago: interim status report. Pp. 57-70 *in* R. W. Grigg and R. T. Pfund (eds.). Proceedings of the symposium on status of resouce investigations in the Northwestern Hawaiian Islands, Honolulu, Hawaii, April 24-25, 1980. UNIHI-SEAGRANT-MR-80-04. Univ. Hawaii Seagrant Program. [P. 107 (Table 3) shows relative abundance of major reef fishes at Laysan and other Northwestern Hawaiian Islands as well as making miscellaneous comments regarding Laysan.]

Hobson, E. S. 1984. The structure of reef fish communities in the Hawaiian archipelago. Pp. 101-122 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-0l. Vol. 1. [Data for all the Northwestern Hawaiian Islands; gives relative abundance of major reef fishes at each atoll,]

Hollenberg, G. J. 1968. An account of the species of the red alga *Polysiphonia*

of the Central and Western tropical Pacific Ocean. II. Polysiphonia. Pacific Sci. 22(2): 198-207. [Reports alga *P. tsudana*, sp. nov. from the neck of a Green Turtle on Laysan 8 December 1963]

Holly, M. 1935. Polychaeta from Hawaii. B. P. Bishop Mus. Bull. 129: 33 pp. [Gives results of Pietschmann's 1928 collections at Pearl and Hermes, French Frigate Shoals, Lisianski and Laysan] [POBSP 1537]

Howard, R. J., and C. A. Newton. 1993ms. Trip Report: Laysan Island, 9 March - 9 August 1993. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, HI. 43 pp. [Notes on *Cenchrus* control, censuses of Laysan Ducks, island wide counts of nests of Black Noddies, Red-footed Boobies and Great Frigatebirds and partial censuses of Red-tailed Tropicbird nests (those in *Cenchrus* study plots), results of shorebird counts, annotated list of breeding and vagrant birds; the least common of the latter was a female American Wigeon (*Anas americana*) seen from 10 May to 11 July. Also gives an annotated list of vascular plants, and notes on the "dead zone", monk seals, green turtles, and on an oil spill. Nesting distributions of Red-tailed Tropicbird, Masked and Brown boobies, Gray-backed and Sooty terns were mapped but not included in report.]

Hornell, J. 1934. Log of the schooner *Ada* on a fishing cruise in the North Pacific, 1882. Mariner's Mirror 20: 436-437.

Howard, R. J., and C. A. Newton. 1993ms. Laysan Island Trip Report (9 March - 9 August 1993). 49 pp. Admin. Rep., U. S. Fish. Wildl. Service, Honolulu, HI. 8 pp. [Mostly on *Cenchrus* problem and eradication]

Howarth, F. G. 1981. New earwigs (Carcinophoridae). Proc. Haw. Entomol. Soc. 23(3): 315. [Earwig previously collected on Laysan and reported in the Insects of Hawaii as *Anisolabis eteronomata* is reidentified as *A. maritima* (Bonelli).]

Hu, D. 1985ms. Trip report: Northwest Hawaiian Islands Cruise, 15 May - 13 June, 1985. 15 pp. Unpublished admin. rep. U. S. Fish and Wildlife Service, Honolulu, HI. [Information on seabirds]

Hu, D. 1987ms. Trip report: Laysan Island, 6 April to 1 May 1987. Unpublished admin. rep. U. S. Fish and Wildlife Service, Honolulu, HI. 13 pp. [Data on seabird biology]

Hudson, O. 1911. Uncle Sam's Ocean Park. Mid-Pacific Magazine 1(3): 339-343. [Brief unimportant descriptions of the Northwestern Hawaiian Islands with a few photographs and some remarks on birds] [POBSP 135]

Humphrey, P. S. 1965. An ecological survey of the central Pacific. Smithsonian Year 1965: 24-30. [Describes the Pacific Ocean Biological Survey Program; has two photos from Laysan.]

Imada, C. T., W. L. Wagner, and D. R. Herbst. 1989. Checklist of native and naturalized flowering plants of Hawai'i. B. P. Bishop Mus. Occ. Pap., vol. 29: 31-97. [Contains entries for Laysan.]

Ito, B. M., and R. N. Uchida. 1980. Results of *Ciguatera* analysis of fishes in Northwest Hawaiian Islands. Pp. 81-89 *in* R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. UNIHI-Seagrant-MR-80-04. [Eight species of fish from Laysan showed positive reactions.]

Ito, B. M., R. N. Uchida, L. M. Shirai, M. A. Abad, L. H. Kimura, and Y. Hokama. 1984. Radioimmunoassay results of ciguatera analysis of fishes in the Northwestern Hawaiian Islands, 1980-81. Pp. 226-236 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-01. Vol. 2. [Table 2 presents results for samples collected 1980-1981 for all the Northwestern Hawaiian Islands. The number of positive results was about intermediate for Laysan where the following species of fish provided borderline or positive assays for ciguatera: *Pseudocaranx dentex*, *Seriola dumerili*, *Etelis carbunculatus*, *Pristipomoides filamentosus*, *P. zonatus*, *Euthynnus affinis*, and *Pontinus macrocephalus*.]

IUCN. 1991. IUCN Directory of Protected Areas in Oceania. Prepared by the World Conservation Monitoring Centre. IUCN, Gland, Switzerland and Cambridge, U.K. xxiii + 447 pp. [2 page section on Hawaiian Islands National Wildlife Refuge, including Laysan, related to ecology and conservation.]

Jabulka, J. 1934. Birds without fear found on Laysan Island. Honolulu Star-Bulletin, July 7, 1934. [Not seen. Based on 1934 visit of USCG cutter Itasca commanded by Commodore John S. Baylis. Historic notes from other sources on Nihoa, Necker, French Frigate Shoals and Laysan. From Bryan 1978]

Jacobs, W. V. E. (ms.). Report to the Secretary of the Treasury of investigation and apprehension of Japanese plumage hunters in January 1910. Rec. Group 26, U.S. Natl. Archives. 18 pp. [POBSP 1547]

Johanos, T. C., and S. L. Austin. 1988. Hawaiian Monk Seal population structure, reproduction, and survival on Laysan Island, 1985. U.S. Dep. Comm., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC 118. 38 pp. [Not 36 pp. as sometimes cited. Based on studies conducted 2 March to 30 November 1985 a total of 295 individuals present an increase of 25 over the preceding year with at least 32 pups born.]

Johanos, T. C., B. L. Becker. M. A. Brown, B. K. Choy, L. M. Hiruki, R. E. Brainard, and R. L. Westlake. 1990. The Hawaiian Monk Seal on Laysan Island, 1988. NOAA Tech. Memo. NMF5-5WFC-151. 44 pp.

Johanos, T.C., B. L. Becker, and T. J. Ragen. 1994. Annual reproductive cycle of the female Hawaiian Monk Seal (*Monachus schauinslandi*). Marine Mamm. Sci. 10(1): 13-30. [Based on studies conducted on Laysan (1982-1992) and Lisianski (1982-1983) islands. Data are given on birth rates, pupping, weaning, and molting.]

Johanos, T. C., A. K. H. Kam, and R. G. Forsyth. 1987. The Hawaiian Monk Seal on Laysan Island: 1984. U.S. Dep. Comm., NOAA Tech. Memo. NMFS, NOAA-NMFS-SWFC-70, 38 pp.

Johnson, A. M., R. L. DeLong, C. H. Fiscus, and K. W. Kenyon. 1982. Population status of the Hawaiian Monk Seal (*Monachus schauinslandi*), 1978. J. Mammal. 63(3): 415-421. [Estimates for Kure, Midway, Pearl and Hermes Reef, Laysan. etc. showing declines in populations 1957-1978]

Johnson, A. M., and E. Kridler. 1983. Interisland movement of Hawaiian Monk Seals. 'Elepaio 44(5): 43-45. [Movements from and/or to reported for Kure, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes Reef and Johnston Atoll.]

Johnson, B. W., and P. A. Johnson. 1978. The Hawaiian Monk Seal on Laysan Island: 1977. Final Rep. Marine Mammal Comm., Contract MM TAC 009, Natl. Tech. Inf. Serv. P.B.-285428. 38 pp.

Johnson, B. W., and P. A. Johnson. 1978. The Hawaiian Monk Seal on Laysan Island: 1977. Final Report. Aquatic Mammals Behav. Res. Co., Honolulu, Hawaii. 46 pp.

Johnson, B. W., and P. A. Johnson. 1980. The Hawaiian Monk Seal on Laysan Island, 1978. Draft report to the Marine Mammal Commission, Washington, DC. 20006. 39 pp. [Not seen, in Gilmartin et al. 1980]

Johnson, B. W., and P. A. Johnson. 1980ms. Hawaiian Monk Seal observations on Laysan Island, 1979. 5 pp. [In files of USFWS, Honolulu. Report of studies made 12 March-17 August]

Johnson, B. W., and P. A. Johnson. 1981a. Estimating the Hawaiian Monk Seal population on Laysan Island. Aquatic Mammals Behav. Res. MMG-80/06. 36 pp.

Johnson, B. W., and P. A. Johnson. 198lb. The Hawaiian Monk Seal on Laysan Island: 1978. Final Rep. Marine Mammal Comm., Contract MM 8AC 008, Natl. Tech. Inf. Serv. PB-82-l0966l. 17 pp.

Johnson, B. W., and P. A. Johnson. 1981ms. Hawaiian Monk Seal observations on Laysan Island, 1980. 5 pp. [Not seen; from Hiruki and Ragen 1992]

Johnson, B. W., and P. A. Johnson. 1984. Observations of the Hawaiian Monk

Seal on Laysan Island from 1977 through 1980. NOAA Tech. Memo. NMFS-SWFC 49, 65 pp.

Johnson, H. M. 1961. Note on the Laysan Duck. 'Elepaio 22(3): 22-23. [Largely notes on a 1960 article by S. D. Ripley] [POBSP 895]

Johnson, P. A., B. W. Johnson, and L. T. Taylor. 1981. Interisland movement of a young Hawaiian Monk Seal between Laysan Island and Maro Reef. 'Elepaio 41(11): 113-114.

Jordan, D. S. and J. O. Snyder. 1904. Notes on collections of fishes from Oahu Island and Laysan Island, Hawaii, with descriptions of four new species. Proc. U.S. Nat. Mus. 27 (No. 1377): 939-948. [Reports fish collected at Oahu and Laysan, the latter collected by Max Schlemmer but does not always give collection localities. Lists 7 species from Laysan including the newly described *Lactoria schlemmeri* and *Antennarius laysanensis*, a synonym of *A. commersoni*.] [POBSP 1637]

Jordan, D. S., and B. W. Evermann. 1905. The aquatic resources of the Hawaiian Islands. Part I. The shore fishes. U. S. Bur. Fisheries Bull. 23(1): i-xxviii & 1-574. [Color plate and detailed description of *Julis flavovittata* Bennett, *Gymnothorax laysanus* (Steindachner), *Lactoria schlemmeri* (Jordan and Snyder), and *Antennarius laysanicus*, all collected on Laysan]

Kam, A. K. H. 1986. The green turtle, *Chelonia mydas*, at Laysan Island, Lisianski Island, and Pearl and Hermes Reef, summer 1982. U. S. Dep. Commer., NOAA Tech. Memo. NOAA-NMFS-SWFC-107, 24 pp.

Kay, E. A. 1979. Hawaiian Marine Shells. B. P. Bishop Museum Spec. Publ. 64(4). xvii & 653 pp. [Laysan is mentioned several times in the introduction. Specific locality records through page 307 for various species are given for Midway (ll), Pearl and Hermes Reef (4), French Frigate Shoals (7 - see Pease l87ld), Gardner Pinnacles (2), Necker (3), Nihoa (2), Kure (l) Laysan (3), (See Rehder and Ladd 1973), Lisiansky (l), Johnston Island (3), Fanning (4 - Kay 197l, Kay and Switzer 1974), Canton (l) (Kay 1976) and some others said to be of wide distribution (e.g. such as from Midway to Hawaii) may also have been recorded from Laysan.]

Keast, A. 1966. Australia and the Pacific Islands: A Natural History. The Continents We Live On Series, Random House, New York. 298 pp. [Pp. 224-228 have derivative material on Laysan; 2 B&W photos, one of the Laysan Duck, the other of a Laysan Albatross colony in 1893.]

Kellogg, V. L. and J. H. Paine. 1910. Mallophaga from the birds of Laysan Island. Entomol. News 2l: 124-125. [Lists 11 species, including one, *Docophorus snyderi*, described as a new species from collections made in May 1902.] [POBSP 381]

Kenyon, K. W. 1966ms. Marine Wildlife Biological Observations in the Leeward Hawaiian Islands 8-27 September 1966. Seattle: Bur. Sport Fish. Wildl., U. S. Fish. Wildl. Serv., 1 December 1966. 48 pp. [Not seen; from Hiruki and Ragen 1992]

Kenyon, K. W. 1973. Hawaiian Monk Seal (*Monachus schauinslandi*). In: Seals. IUCN. Survival Service Commission. IUCN Publ. New Series Supplementary Paper 39: 88-97.

Kenyon, K. W. 1978. Hawaiian Monk Seal. Pp. 212-216 *in* D. Haley (ed.) 1978. Marine mammals of the Eastern North Pacific and Arctic waters. Pacific Search Press, Seattle. 256 pp.

Kenyon, K. W. 1981a. The Hawaiian Monk Seal: an endangered marine mammal. Water Spectrum 13(2): 1-6. [Pp. 4-5 mention productivity 1977-1980 and ciguetera poisoning; p. 6 shows a seal along the beach there.]

Kenyon, K. W. 1981b. Monk Seals -- *Monachus* Fleming, 1822. Pp 195-220 *in* S. H. Ridgway and R. J. Harrison (eds.). Handbook of Marine Mammals. Vol. 2. Seals. Academic Press, New York. xv & 359 pp.

Kenyon, K. W. 1986. Hawaiian Monk Seal. Pp. 234-242 in D. Haley (ed.). 1978. Marine mammals of the Eastern North Pacific and Arctic waters. 2nd ed., revised. Pacific Search Press, Seattle. 295 pp. [Some material in addition to earlier version; on p. 239 mentions evidence of shark attack at Laysan and Lisianski and mentions of ciguatera at former. Most information on Midway and French Frigate Shoals.]

Kenyon, K. W., and E. Kridler. 1969. Laysan Albatross swallow indigestible matter. Auk 86(2): 339-343. [Data largely from 100 carcasses on Southeast island, Pearl and Hermes Reef 24 Sept. 1966; gives also a few observations at Laysan.] [POBSP 1558]

Kenyon, K. W., and D. W. Rice. 1959. Life history of the Hawaiian monk seal. Pacific Sci. 13(3): 215-252. [POBSP 269]

Kepler, A. K. 1992ms a. Easy Guide to Laysan's Plants. in. 5. Fish & Wildlife Service, Honolulu, Hawaii. 18 pp. [An illustrated typescript that identifies all plants occurring there]

Kepler, A. K. 1992ms b. Trip Report: Laysan Island, January 15 to April 25, 1992. Admin. Rep. U. S. Fish and Wildlife Service, Honolulu, Hawaii. 105 pp. [Detailed report on a wide variety of topics including both vertebrates and plants with many maps.]

Kimura, L. H., Y. Hokama, and M. A. Abad. 1984. Results of ciguatoxin analysis by enzyme-immunoassay (EIA) of fishes in the nearshore waters of the Northwestern

Hawaiian Islands. Pp. 108-121 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-0l. Vol. 2. [Data based on fish captured at all the Northwestern Hawaiian Islands including Laysan. Table 6 presents specific results for Acanthurus triostegus and Kuhlia sandvicensis samples from Laysan and other islands. Other fish from Laysan that were tested were *Abedufdef sordidus*, *Bodianus bilunulatus*, *Caranx ignobilis*, *Cheilinus rhodochrous*, *Mulloidichtys flavolineatus*, and *Thalassoma purpurem*.]

King, J. E. 1956. The monk seals (Genus *Monachus*). Bull. Brit. Mus. (Nat. Hist.) Zool. 3(5): 201-256. [POBSP 278]

King, J. E. 1964a. The monk seal of the Pacific. Zeitschr. Saugetierkunde 29(1): 37-42. [General account mentioning all islands and giving population estimates 1824-1958; also with photos of seal on Laysan.]

King, J. E. 1964b. Seals of the World. British Museum (Nat. Hist.), London. 154 pp. [Brief natural history on pp. 75-77 of the "Laysan Monk Seal".]

King, J. E., and R. J. Harrison. 1961. Some notes on the Hawaiian Monk Seal. Pacific Sci. 15(2): 282-293. [Notes on specimen collected on Laysan during the summer of 1958] [POBSP 255]

King, R. D. 1941. Leeward Islands and Palmyra. Thrum's Hawaiian Annual 1940-41, pp. 45-53. [Geographic, statistical, and historic data about Laysan on pp. 49-50.]

King, W. B. 1973. Conservation status of birds of central Pacific islands. Wilson Bull. 85(8): 89-103. [About 1/2 page devoted to Laysan on pp. 91-92.]

King, W. B. (ed.). 1974. Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zool., no.158. 277 pp. [Papers included by King, P. G. Gould, R. S. Crossin, C. S. Robbins and D. W. Rice, and G. A. Sanger, and listed elsewhere herein are based largely on the researches of the Pacific Ocean Biological Survey Program.]

King, W. B. 1974. Wedge-tailed Shearwater. Pp. 53-95 in: W. B. King, (ed.), Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zoo., no.158. [Pelagic range maps and sightings, including waters around Laysan].

King, W. B. 1981. Endangered Birds of the World. The ICBP Red Data Book, Smithsonian Institution Press/lCBP, Washington, DC. [Detailed discussions of extinct and endangered Laysan birds]

Kittlitz, F. H. von. 1834. Nachricht von den Brutplatzen einiger tropischen Seevögel im Stillen Ocean. Mus. Senckenb. 1: 115-126. [Brief description of Moller [Laysan] and Lisianski islands with notes on the birds found there. Includes a brief mention of vegetation as observed by Kittlitz and C. Isenbeck. A partial translation can be found in Rothschild 1893-1900] [POBSP 1720]

Knudtson, E. P. 1980 ms. Hawaiian Monk Seal (*Monachus schauinslandi*), survey of the Northwest Hawaiian Isles, 3-22 November 1980. Honolulu, NMFS, Southwest Fish. Center Lab. 6 pp. [Not seen; from Hiruki and Ragen 1992]

Knudtson, E. P. 1981 ms a. Hawaiian Monk Seal, *Monachus schauinslandi*, survey of the Northwestern Hawaiian Islands, 17 January-3 February 1981. NMFS, SWFC Honolulu Lab. 4 pp. [Not seen; from Hiruki and Ragen 1992]

Knudtson, E. P. 1981 ms b. Hawaiian Monk Seal observations at Laysan Island, March-July 1981. Southwest Fisheries Science Center Honolulu Laboratory, National Marine Fisheres Service, NOAA, 23 pp.] [2570 Dole St., Honolulu, HI 96822-2396.

Knudtson, E. P. 1983 ms. Survey of the Hawaiian Monk Seal, Monachus schauinslandi, at Laysan Island, 25-28 January 1981. 3 pp. [In files of USFWS, Honolulu, HI]

Knudtson, E. P., and M. Naughton. 1979. Colony attendance patterns and wing characteristics of some tropical seabirds. Pac. Seabird Group Bull. 6(2): 30. [Abstract only. Laysan studies briefly described]

Kohls, G. M., D. E. Sonenshine, and C. M. Clifford. 1965. The systematics of the subfamily Ornithodorini (Acarina: Argasidae). II. Identification of the larvae of the western hemisphere and descriptions of three new species. Ann. Entomol. Soc. Amer. 58(3): 331-334. [*Ornithodoros* (*A.*) *capensis* larvae described in part from larvae reared from adults taken in December 1963 from a Laysan Albatross nest on Laysan.]

Kramer, R. J. 1959ms. Some notes and observations on Laysan Island Fauna, April 28, 1959 to May 1, 1959. 8 pp. Hawaii Div. Fish and Game, Honolulu, HI. [Most of report on Hawaiian Monk Seal and Laysan Duck, with very brief notes on other birds.] [POBSP BB 8]

Kramer, R. J. 1963ms. A report on a survey trip to the Hawaiian Islands National Wildlife Refuge, February, 1963. 29 pp. [Report by employee of the Hawaii Division of Fish and Game on POBSP survey of Laysan (11-13 February) and Lisianski (14 February) islands. Reports observations on vegetation affected by winter weather, birds, seals, turtles, and remains of military operations. Also includes information on turtle tagging and photographs (originals presumably still in the possession of the Hawaii Division of Fish and Game) showing both islands] [POBSP 161]

Kramer, R. J. 1971. Hawaiian land mammals. Rutland, Vermont: Charles E. Tuttle Co. 347 pp. [Mention of Laysan under Guinea Pig, Rabbit, Hawaiian Monk Seal.]

Kramer, R. J., and J. W. Beardsley. 1962ms. A report of a survey trip to the Hawaiian Islands National Wildlife Refuge, June, 1962. Hawaii State Dep. Land Nat. Resour., Div. of Fish and Game. 12 pp. [POBSP 154]

Kridler, E. 1964ms. [Report on Hawaiian Islands National Wildlife Refuge... survey September 16 through 27, 1964]. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 31 pp.

Kridler, E. 1966ms a. Hawaiian Islands National Wildlife Refuge trip report, March 17-April 16, 1966. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 24 pp.

Kridler, E. 1966ms b. Hawaiian Islands National Wildlife Refuge trip - September 8-28, 1966. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 34 pp.

Kridler, E. 1967ms a. Refuge log book for 6 March - 1 April 1967. 39 pp.

Kridler, E. 1967ms b. Preliminary report of Leeward Survey No. 18, March 6-27, 1967. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu HI. [Not seen; from Hiruki and Ragen 1992]

Kridler, E. 1967ms c. Refuge log book for 19-29 September 1967. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 12 pp.

Kridler, E. 1967ms d. Hawaiian Islands National Wildlife Refuge...Preliminary trip report - December 7 through 18, 1967. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 13 pp.

Kridler, E. 1968ms a. Summary of recent trip to Hawaiian Islands Refuge, March 6-30, 1968. Admin. Rep. U. S. Fish Wildl. Serv., Honolulu HI. 5 pp. [Not seen; from Hiruki and Ragen 1992]

Kridler, E. 1968ms b. Trip report--Report on recent trip to Hawaiian Islands Refuge, August 23-September 16, 1968. Admin. Rep. U. S. Fish Wildl. Serv., Honolulu HI. 5 pp. [Not seen; from Hiruki and Ragen 1992]

Kridler, E. 1969ms a. Hawaiian Islands National Wildlife Refuge spring trip. March 19 - April 6, 1969. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 32 pp.

Kridler, E. 1969ms b. Hawaiian Islands National Wildlife Refuge Field trip report, August 19 - September 23, 1969. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv.,

Honolulu, HI. 32 pp.

Kridler, E. 1970ms. Hawaiian Islands National Wildlife Refuge Field Trip Report. August 1970. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 19 pp. [Report of visit to Nihoa, Laysan, Lisianski, and Midway. For Laysan, visited 18-20 August, notes are given for all species of birds recorded, as are details of finch and teal censuses, notes on the Green Turtle and tagging, censusing, and recoveries of the Hawaiian Monk Seal.]

Kridler, E. 1971ms. Hawaiian Wildlife Refuge Trip Report. September 2-17, 1971. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 29 pp. [Report of visit to Lisianski, Laysan, Gardner Pinnacles, French Frigate Shoals, Necker and Nihoa. For Laysan, visited 6-11 September, notes on birds are given with more detailed notes on censuses of Hawaiian Monk Seal, Laysan Duck and Laysan Finch. The island was also visited by Eric Laysan Schlemmer who pointed out remnants of the guano operation while he was being the subject of a taped interview.]

Kridler, E. 1972ms. Expedition report. Hawaiian Islands National Wildlife Refuge, September 3-17, 1972. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 28 pp. [Notes for Kure, Midway, Pearl and Hermes, Laysan, French Frigate Shoals, Necker and Nihoa. Laysan visited 10-13 Sep with counts and estimates given for all species of birds and details given for censuses of Laysan Duck, Laysan Finch and Hawaiian Monk Seal.]

Labrecque, A. 1957. A trip to Laysan Island. 'Elepaio 18(3): 16-19. [General observations of birds and the Hawaiian Monk Seal made during a visit 8-12 July 1957.] [POBSP 834]

Lack, D. 1970. The endemic ducks of remote islands. Wildfowl 21: 1-5. [Laysan Duck and its relations are briefly discussed; secondary source]

Lamoureux, C. H. 1963a. The flora and vegetation of Laysan Island. Atoll Res. Bull. 97: 1-14 (with 13 figures). [POBSP 1369]

Lamoureux, C. H. 1963b. Vegetation of Laysan. Proc. Hawiian Acad. Sci. 37: 22. [Abstract only] [POBSP 282]

Lamoureux, C. H. 1964. The Leeward Hawaiian Islands. Newsletter of the Hawaiian Botanical Society 3(2): 7-11. [POBSP 316]

Lamoureaux, C. H. 1985. Restoration of native ecosystems. Pp. 422-431 *in* C. P. Stone and J. M. Scott (eds.). 1985. Hawai'i's terrestrial ecosystems: Preservation and Management. Honolulu, Univ. Hawaii Press. 584 pp. [Includes previous records about the birds of Laysan.]

Laycock, G. 1970. The Hawaiian Islands of birds. Audubon 72(1): 44-61. [Report of USFWS visit to NWHI on the Buttonwood in March-April 1969; has about two pages on Laysan.] [POBSP 1759]

Laycock, G. 1970. Haunted sands of Laysan. Audubon 72(2): 42-49. [Also in 1975 as pp. 163-170 in L. Line (ed.), The pleasure of birds. An Audubon treasury. J. B. Lippincott Company, Philadelphia & New York. 1-191. [Historical photographs and some comments on trip up chain on Buttonwood.] [POBSP 1759]

Lemmermann, E. 1905. Die Algenflora der Sandwich-Inseln. Ergebnisse einer Reise nach dem Pacific, Schauinsland 1896-97. Bot. Jahrb. 34: 607-663. [Reports 45 species of algae that were collected by Schauinsland; citation inadvertently omitted from Clapp and Ely 1973.] [POBSP 1601]

Lenz, H. 1901. Ergebnisse einer Reise nach dem Pacific, (Schauinsland 1896-97). Crustaceen. Zoo. Jahrb. Syst., 14: 429-482. [Reports 25 species of Crustacea. Reference inadvertently omitted from Ely and Clapp 1973.] [An English translation is in POBSP 298]

Lenz, P. H. 1984ms. Trip report, Laysan Island, March/April 1984. 15 pp. U. S. Fish and Wildl. Service, Honolulu, HI. [Not seen, in Newman 1988]

Lenz, P. H., and G. L. Dana. 1987. Life-cycle studies in *Artemia*: a comparison between a sub-tropical and a temperate population. Pp. 89-100 in P. Sorgeloos, D. A. Bengtson, W. Decleir, and E. Jaspers (eds.). *Artemia* research and its applications. Vol. 3. Ecology, Culturing, Use in aquaculture. Universa Press, Wetteren, Belgium. 556 pp. [Comparison of Laysan and Mono Lake, California]

Leroux, L. A., and A. A. Edmonds. 1995ms. Trip Report: Laysan Island, 6 March to 18 July 1995. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, HI. 42 pp and 6 unnumbered pp. of figures. [Details of *Cenchrus* control, censuses of Red-footed Booby and Great Frigatebird nests over the entire island and censuses of Laysan Ducks and Laysan Finch. Also gives partial census of Red-tailed Tropicbird, Masked Booby and Brown Booby nests (those in *Cenchrus* study plots). Gives notes on plant, *Mariscus pennatiformis*, weather, the "dead zone" Also gives an annotated list of breeding birds and vagrants. The most notable vagrant was a Greater White-fronted Goose (*Anser albifrons*) first seen 3 May, found dead 20 June and photographed but not preserved.]

Lint, K. C. 1960. Preserving the Laysan Teal. Zoonooz 33(8): 6-7. [POBSP 1194]

Lipman, V. 1984. The Life, Death and Rebirth of an Island. Honolulu Magazine, November 1984, 7 pp. [Historical account, focusing on Max and Eric Schlemmer, a few old pictures.]

Lombard, K. B., B. L. Becker, M. P. Craig, G. C. Spencer, and K. Hague-Bechard. 1994. The Hawaiian Monk Seal on Laysan Island, 1990. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-206. 16 pp. [Report of studies conducted 10 April-9 August and 14 October-4 November. Data given on behavior, populations, reproduction, and factors affecting survival. 98 seals were tagged and interisland movement is documented for 12 seals that moved between Laysan, Lisianski, French Frigate Shoals, and Pearl and Hermes Reef.]

Lydgate, J. M. 1914. Wrecks to the North-West. Hawaiian Almanac and Annual for 1915; 133-144. [Mentions wrecks on all the Northwestern Hawaiian Islands except Kure]

Lyons, A. B. 1890. In bird land. Part of the journal of a visit to Laysan Island. The Friend, December 1890: 90-91. [POBSP 1264]

Maa, T. C. 1962. Notes on the Hippoboscidae (Diptera), I. Pacific Insects 4(3): 583-614. [Lists louse-fly records from Necker, Nihoa, French Frigate Shoals, Lisianski, and Laysan. Specimens of *Olfersia spinifera* (Leach) are listed (p. 602) as having been collected on Laysan in August 1930 and in April/May 1959. More precise dates than appearing in this paper are 2-18 August and 28 April-1 May (Ely and Clapp 1973)] [POBSP 1633]

Maa, T. C. 1968. Records of Hippoboscidae (Diptera) from the Central Pacific. J. Med. Entomol. 5(3): 325-328. [Reports specimens collected on Laysan 1963-1967 by the POBSP] [POBSP 1665]

MacCaughey, V. 1916. The little end of Hawaii. J. Geogr. 16: 23-26, 15: 23-26.

MacCaughey, V. 1918. Algae of the Hawaiian archipelago. Bot. Gaz. 65(1): 42-57, 65(2): 121-149. [POBSP 1624, 1625]

MacCaughey, V. 1918. A survey of the Hawaiian coral reefs. Amer. Nat. 52: 409-438, 620-621. [p. 417 has a rather indifferent map of Laysan, showing the reef.] [POBSP 212]

MacCaughey, V. 1918. The Endemic Palms of Hawaii: *Pritchardia*. The Plant World 21(12): 317-327. [Thorough botanical account of the genus, mentioning all representatives, including *P. eriophora & P. remota*).

MacDonald, G. A., and A. T. Abbott. 1970. Volcanoes in the sea. The geology of Hawaii. Honolulu, Univ. Hawaii Press. 441 pp. [Pp 400-409 deals with the Northwestern Hawaiian Islands with Laysan described on pp. 404-405. Seems almost entirely derivative.]

Maciolek, J. A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. B.

P. Bishop Mus. Occ. Pap. 25(1): 1-14. [Laysan mentioned and figured on pp. 4-5.]

Manning, A. 1982. Hawaiian and Laysan Rails: 5. B. Dole corresponds with A. Agassiz. 'Elepaio 42(10): 87-88. [Peripheral].

Marks, J. S. 1988ms. Trip Report Summary, Laysan Island, Fall 1988. 11 pp.

Marks, J. S. 1990. Streaked Shearwater (*Calonectris Ieucomelas*) on Laysan Island: First documented record for Hawaii. 'Elepaio 50(4): 31-32. [Includes photograph of bird present 1-2 August 1989]

Marks, J. S. 1991ms a. Trip report summary, Bristle-thighed Curlew research, Laysan Island, summer/autumn 1990. Unpubl. rep., Montana Cooperative Wildl. Res. Unit., Univ. Montana, Missoula. 14 pp. [Studies conducted 12 August - 30 November concentrated on population structure, molt, flightlessness, and annual survival by age class. Details are also provided on banding.]

Marks, J. S. 1991ms b. Trip report summary, Bristle-thighed Curlew research, Laysan Island, winter/spring 1991. 17 pp. [Summary of observations made 2 February - 14 June 1991 with details on population numbers and structure, molt, migration, seasonal changes in bill color.]

Marks, J. S. 1992. Longevity record for the Bristle-thighed Curlew: an extension. J. Field Ornithol. 63(3): 309-310.

Marks, J. S. 1993ms. Trip report, Bristle-thighed Curlew research, Laysan Island, 9-12 March 1993. Unpubl. rep., Montana Cooperative Wildl. Res. Unit, Univ. Montana, Missoula, MT. 7 pp. [Brevity of visit largely restricted observations largely to previously banded curlews; also provides records for a number of seldom recorded species: Northern Pintail, Green-winged Teal, Bufflehead, Whimbrel, and a note on an albino Black Noddy]

Marks, J. S. 1993 (1994). Molt of Bristle-thighed Curlews on the Northwestern Hawaiian Islands. Auk 110(3): 573-587. [Most of information based on studies on Laysan Island from 1988 to 1991. The rapidity of molt, about 92 days, resulted in about 50% of the birds becoming flightless during molt, and presumably developed only because these birds winter on predator-free islands.]

Marks, J. S., and D. L. Evans. 1988ms. Bristle-thighed Curlew Study: Laysan and Lisianski Islands, Northwestern Hawaiian Islands, Spring 1988. Trip Report, U. S. Fish & Wildlife Service, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana. 18 pp, 3 tbls., 13 figs. [Data on populations, banding, molt, morphology, habitats and migration

Marks, J. S., and C. S. Hall. 1992. Tool use by Bristle-thighed Curlews feeding

on albatross eggs. Condor 94(4): 1032-1034.

Marks, J. S., and P. Hendricks. 1989. On the flushing behavior of incubating White Terns. Condor 91(4): 997-998.

Marks, J. S., P. Hendricks, D. L. Evans, and R. L. Redmond. 1989ms. Annual Report. Bristle-thighed Curlew Study: Laysan and Lisianski Islands, Northwestern Hawaiian Islands, 1988. Unpubl. rep., Montana Cooperative Wildl. Res. Unit, Univ. Montana, Missoula, MT. 61 pp. [Studies conducted on Laysan 30 April-14 May focused on populations, timing of migration, importance of Laysan and the other Northwestern Hawaiian Islands as a migratory stopover, molt, food habits, local movements and habitat use. Details are also provided on banding, morphology by age class and season, behavior]

Marks, J. S., and S. M. Leasure. 1992. Breeding biology of Tristram's Storm-Petrel on Laysan Island. Wilson Bull. 104(4): 719-731.

Marks, J. S., and R. L. Redmond. 1989ms. Annual Report. Bristle-thighed Curlew Study: Laysan Island, Northwestern Hawaiian Islands, 1989. Unpubl. Rep., Montana Cooperative Wildl. Res. Unit, Univ. Montana, Missoula, MT. 42 pp. [Observations 13-18 June on Tern Island, French Frigate Shoals and 28 June-9 September on Laysan. In addition a wide variety of observations on the curlew, Great Frigatebirds were mapped and censused, Laysan Finches were censused and monitored for color bands, and three monk seals were tagged.]

Marks, J. S., and R. L. Redmond. 1994a. Migration of Bristle-thighed Curlews on Laysan Island; timing, behavior and estimated flight range. Condor 96(2): 316-330.

Marks, J. S., and R. L. Redmond. 1994b. Conservation problems and research needs for Bristle-thighed Curlews *Numenius tahitiensis* on their wintering grounds. Bird Conserv. Internatl. 4: 329-341. [Laysan is mentioned often with a wintering population of 300-400 birds listed. A summary table summarizes known population data for various Pacific islands, with estimates for the Northwestern Hawaiian Islands as a whole and therein, individually for Lisianski Island and Midway Atoll.]

Marks, J. S., R. L. Redmond, P. Hendricks, R. B. Clapp, and R. E. Gill, Jr. 1990. Notes on longevity and flightlessness in Bristle-thighed Curlews. Auk 107(4): 779-781. [Largely based on observations at Laysan]

Marks, J. S., and L. G. Underhill. 1994. Moult, migration and mass of a handicapped Bristle-thighed Curlew *Numenius tahitiensis*. Ardea 82(1): 153-156.

Marshall, A. P. 1990. The behavior of Laysan Ducks (*Anas laysanensis*) in captivity and on Laysan Island. Ph.D. diss. Ohio State Univ. 220 pp. [Not seen]

Marshall, A. P. 1992. Censusing Laysan Ducks *Anas laysanensis*: a lesson in the pitfalls of estimating threatened species populations. Bird Conserv. Internatl. 2(4): 239-25l. [Comparison and evaluation of different censusing methods and their implications for management. Includes original observations made on Laysan in 1986 and 1987.]

Marshall, A. P. 1993. The status of the Laysan Duck. IWRB Threatened Waterfowl Res. Group Newsl. No. 3: 11-12. [Remarks on history, habitat, current status and monitoring difficulties]

Marshall, D. B. 1962ms. Report of Hawaiian Islands National Wildlife Refuge inspection trip, June 6 through 26, 1962. Bureau of Sport Fisheries and Wildlife, U. S. Dept. of the Interior, Honolulu. 8 pp. [Visit by LST and helicopter to Nihoa (7 hours), Necker (1 hour), French Frigate Shoals and Laysan (5 1/2 days) provides useful information but no dates for visits to any of the atolls. Documents the presence of the military of the Pacific Missile Range on these islands (and Gardner Pinnacles) during that period] [POBSP 167]

Marshall, D. B. 1964. Treasure islands--of wildlife. Audubon Mag. 66(3): 160-165. [POBSP 1103]

Matschie, G. F. P. 1905. Eine Robbe von Laysan. Sitzungsbericht der Gesellschaft naturforschender Freunde Berlin, pp. 254-262. [Description of *Monachus schauinslandi* based on Schauinsland's specimen] [POBSP 328, English translation]

Mayer, A. G. 1906. Medusae of the Hawaiian Islands collected by the steamer Albatross in 1902. U.S. Fish. Comm. Bull 23 (3): 1131-1143. [Reports hydromedusae collected offshore Laysan.] [POBSP 1568]

MacBryde, B. 1983. Endangered and threatened wildlife and plants; supplement to review of plant taxa for listing; proposed rule. Fed. Reg. 48: 53639-53670. [Not seen; from Mill et al. 1988]

McDermond, D. K. 1987ms. Trip Report: French Frigate Shoals to Midway Island, 21 May - 11 June, 1987. Admin. Rep., U.S. Fish. Wildl. Serv., Honolulu, Hawaii. 10 pp. [Includes notes on vegetation, a nest count for Great Frigatebird by nest site (totaling 4902 nests), and banding data]

McDermond, D. K. 1988ms. Trip Report: Honolulu to Midway Atoll, 5 June - 7 July, 1988. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, Hawaii. 22 pp. [Notes on various birds including a count of 521 Red-footed Booby nests, the discovery of 342 dead white-headed juvenile Great Frigatebirds, and note on gradual increased in Black Noddy colonies and nesting numbers since 1986 when few birds nested.]

McDermond, D. K. 1994. Regional Reports. Pacific Rim. Pacific Seabirds 21(1): 31-33. [Reports on V. Gauger's study of Black Noddies.]

McDermond, D. K., and E. Bean. 1986ms. Trip Report: Biological Monitoring, Laysan Island, February 20 - August 4, 1986. U. S. Fish Wildl. Serv., Hawaiian and Pacific Complex National Wildlife Refuge. 41 pp. [Seabird population populations and/or status assessed with remarks on the effect of a severe storm. Also provides observations on plants, lagoon levels, and other activities taking place on Laysan and maps nesting areas of Sooty Storm Petrels, Masked, and Red-footed boobies, Sooty Terns, Black Noddies, and Sooty Tern. Of particular interest is the observation that 44 of 60 Black-footed Albatross and all 22 Laysan Albatross chick's whose proventriculus contents were examined were found to contain plastic objects.]

McDermond, D. K., E. N. Flint, M. A. Webber, and C. A. Newton. 1995. Control of alien plant *Cenchrus echinatus* on Laysan Island. Pacific Seabirds 22(1): 38. [Abstract describing methods and partial results of a monitoring and control program]

McDermond, D. K., and K. H. Morgan. 1993. Status and conservation of North Pacific albatrosses. Pp. 70-81 in K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey (eds.). The status, ecology and conservation of marine birds of the North Pacific. Ottawa, Can. Wildl. Serv. Spec. Publ.

Meadows, R. 1994. Mobbing and the male Monk Seal. Zoogoer, Nov.-Dec., p. 24-25. [General account of mobbing problem on Laysan; notes that 22 adult males were removed in late July and early August 1994]

Merrill, C. F. 1917. Feathered migrants. Mid-Pacific Magazine 14(3): 277-279. [Includes illustations of birds on Laysan] [POBSP 1006]

Meyrick, E. 1900. New Hawaiian *Lepidoptera*. Entomol. Mon. Mag. Ser. 2, 11: 257-258. [Describes noctuids *Agriotis eremioides* and *A. procellaris*, both endemic to Laysan, from specimens collected by Schauinsland] [POBSP 1606, 1621]

Michaelsen, W. 1899. Oligochäten von der Inseln des Pacific, nebst Erörterungen zur Systematik der Megascoleciden. (Ergebnisse einer Reise nach dem Pacific, Schauinsland 1896-97). Zool. Jahrb., Syst. 12: 211-246. [Describes a new variety of earthworm from Laysan (*Pontodrilus ephippiger* Rosa var. n. *laysanius*) from specimen collected by Schauinsland] [Original and English translation in POBSP 1594]

Mill, S. W., D. P. Gowing, D. R. Herbst, and W. L. Wagner. 1988. Indexed bibbliography on the flowering plants of Hawaii. Bishop Mus. Spec. Publ. 82. vi & 214 pp. [Lists 18 references to Laysan, all incorporated here]

Möhle, F. 1902. Beitrag zur Petrographie der Sandwich/- und Samoa-Inseln. Neues. Jahrb. Mineral., Geol., Paleontol. Beilageband 15: 66-104. [Reports studies of a few rock samples collected by Schauinsland] [POBSP 1635]

Morin, M. P. 1987. Laysan Finches drown as a result of marine debris. 'Elepaio

47(11): 107-108. [Two dried, dead birds found in the bottom half of a water cooler on 16 June 1986]

Morin, M. P. 1987ms. 1987 Field Season Laysan Finch Report, Laysan Island. Admin. Rep. to U. S. Fish. Wildl. Serv., Honolulu, Hawaii, Dec. 1987. 8 pp.

Morin, M. P. 1989ms. 1988 Laysan Finch report, Laysan Island. Admin. Rep. to U. S. Fish Wildl. Service, Honolulu, HI. 9 pp.

Morin, M. P. 1991. The breeding ecology of the Laysan Finch (Drepanidinae: *Telespiza cantans*) on Laysan Island. Ph.D. diss., Univ. Hawaii, Manoa, Honolulu.

Morin, M. P. 1992a. Laysan Finch nest characteristics, nest spacing and reproductive success in two vegetation types. Condor 94(2): 344-357. [Comparison between sites in predominant vegetation associations: bunchgrass and viney based on studies conducted from 1986 to 1988]

Morin, M. P. 1992b. The breeding biology of an endangered Hawaiian Honeycreeper, the Laysan Finch. Condor 94(3): 646-667. [Provides information on pairing, territorial behavior, breeding season, clutch size, nesting success and factors affecting success based on studies conducted from 1986 to 1988.]

Morin, M. P., and S. Conant. 1990. Nest substrate variation between native and introduced populations of Laysan Finches. Wilson Bull. 102(4): 591-604. [Based on 1984-1988 observations at Laysan and 1984 and afterwards at Pearl and Hermes Reef. The species nests almost exclusively in a native bunchgrass *Eragrostis variabilis* on Laysan but a variety of sites were used by introduced birds on Pearl and Hermes where *Eragrostis* is uncommon.]

Morin, M. P., and S. Conant. 1994. Variables influencing population estimates of an endangered passerine. Biol. Conserv. 67: 73-84. [Overview of all Laysan Finch estimates on Laysan with emphasis on analysis of 7 transects taken 1986-1988]

Morris, C. 1899. Our island empire: a hand-book of Cuba, Porto Rico, Hawaii, and the Philippine Islands. J. P. Lipincott Co., Philadelphia, PA. 488 pp. [Has section on "Bird Products" of Hawaii focusing on Laysan. Also reports swine production and that one buccaneer stole all pigs, salted them and sailed away unknown to the resident manager of Laysan.]

Morris, P. C. 1934. How the Territory of Hawaii grew and what domain it covers. Hawaiian Historical Society 42nd Annual Report for 1933: 13-39.

Morton, T. [189?] Laysan, a bird paradise. Pearson's Mag, 672-677. [POBSP 627]

Moulton, D. W., and M. W. Weller. 1984. Biology and conservation of the Laysan Duck (*Anas laysanensis*). Condor 86(2): 105-117. [Based on studies made from 12 March to 17 August 1979 and 15-17 March and from 6 April to 29 August 1979. Information given on populations, breeding and feeding biology, weights, molt, mortality, daily activity patterns, habitat use, and flight behavior and capacity.]

Munro, G. C. 1930. Myriad-nested Laysan. Asia 30: 686-689. [POBSP 221]

Munro, G. C. 1940. A vanishing bird. 'Elepaio 1(4): 1. [Concerns a high island bird but includes a paragraph on the Laysan Finch and its ecology] [POBSP 647]

Munro, G. C., 1941-1943. Birds of Hawaii and adventures in bird study. An Ocean Cruise. Parts 1-12. 'Elepaio 2: 34-36; 41-43; 49-51; 56-58; 63-64, 67-68, 72-73, 77-78; 'Elepaio 3: 2-3, 5, 6, 7-9; 12-13; 15-16; 18-19; 22-23; 26-27.[Parts 7 and 8 (italics) describe the trip to Laysan in 1891. Other parts specifically mentioning Laysan are listed below.]

Munro, G. C. 1941a. Birds of Hawaii.. [the Wedge-tailed Shearwater]. 'Elepaio 1(7):1-3; 1(8): 1-4. [POBSP 664]

Munro, G. C. 1941b. Birds of Hawaii.. .Bulwer's Petrel. 'Elepaio 2(1): 1-3. [POBSP 668]

Munro, G. C. 1941c. Birds of Hawaii. . .The Christmas Island Shearwater. 'Elepaio 2(3): 16-18. [Brief observations on French Frigate Shoals, Lisiansky, Laysan, and Eastern Island, Midway Atoll] [POBSP 670]

Munro, G. C. 1942a. Birds of Hawaii. . An Ocean Cruise. No. 7. 'Elepaio 2: 72-73, 77-78. [POBSP 673]

Munro, G. C. 1942b. Birds of Hawaii...An Ocean Cruise. No. 8. 'Elepaio 3(1,3): 2-3, 5-6. [Remarks on the vegetation, Laysan Rail, Laysan Finch and Laysan Duck in 1891. Documents egg-eating by the rail, finch, and Bristle-thighed Curlew and notes a great abundance of flies.]

Munro, G. C. 1943. Birds of Hawaii...some breeding and feeding habits of sea birds. 'Elepaio 4(5): 17-18, (6): 23-25. [Data on Laysan seabirds]. [POBSP 869]

Munro, G. C. 1944. Birds of Hawaii. Tongg Publ. Co., Honolulu. 189 pp. [POBSP 1020] [Reprinted by Tuttle, Rutland, VT., and Tokyo, 1960.

Munro, G. C. 1945a. Tragedy in Bird Life. 'Elepaio 5(8): 48-49. [Narrative of richess of bird populations on Laysan] [POBSP 683]

Munro, G. C. 1945b. Endangered bird species of Hawaii. 'Elepaio 5(12): 76-79,

6(1): 1-6. [Comments on plume hunters and effects of introduction of rabbits on Laysan. P. 3 mentions Laysan Finches being brought to Oahu in 1898.]

Munro, G. C. 1946a. Notes on the Black-footed and Laysan Albatrosses. 'Elepaio 7(5:) 28-29. [Sight record of albino *Diomedea immutabilis* on Laysan]. [POBSP 708]

Munro, G. C. 1946b. Laysan Island in 1891. 'Elepaio 6: 51-52, 60-61, 66-69. [Reprint of article first published in Asia Magazine] [POBSP 700]

Munro, G. C. 1947. Notes on the Laysan Rail. 'Elepaio 8(5): 24-25. [Ecological notes on birds on Laysan and Midway] [POBSP 721]

Munro, G. C. 1953. Cannibalism in Firgate [sic] Birds. 'Elepaio 13(8): 56-57. [Notes on behavior on Laysan, Lisianski and central Pacific equatorial islands] [POBSP 789]

Munro, G. C. 1960. *Oceanodroma tristrami* Sooty Storm Petrel. 'Elepaio 20(11): 75-76. [Corrects error re Schauinsland report in Birds of Hawaii.] [POBSP 880]

Munter, W. H. 1915. Report of destruction of bird life on Laysan Island. Ann. Rep. Coast Guard for 1915: 130-140.

Munter, W. H. 1916 ms. Report to the captain of the Thetis of bird observations made during a cruise to the Hawaiian Bird Reservation in January and February 1916. Rec. Group 26, U.S. Nat. Arch. 19 pp. [Several pages of notes on birds observed at French Frigate Shoals, Pearl and Hermes Reef, Lisianski, Laysan (9 February), Necker, and Nihoa. Collections made of various materials at Laysan including beach sand and shells.]

Murphy, R. 1968. Wild Sanctuaries: Our National Wildlife Refuges - a Heritage Restored. E. P. Dutton & Co., Inc., New York. 287 pp. [Excellent discussion of Laysan, with aerial photo of island, several pages. Concentrates on Laysan rather than Midway or French Frigate Shoals, as is done in most other discussions of the NWHI Refuge.]

Nakamura, K. 1982. Sooty Tern, *Sterna fuscata* of Japan. Bull. Kanagawa Prefect. Mus. Nat. Sci. 13: 37-50. (In Japanese with English abstract.) [Recoveries of central Pacific Sooty Terns in Japan include two from Laysan, one previously unreported. Other islands contributing recoveries were Wake (2), Johnston Atoll (8), Midway, Lisianski, Taongi, Kure and Eniwetok (one each).]

Naughton, M. 1982. Breeding biology of the Christmas Island Shearwater (*Puffinus nativitatis*) on Laysan Island, Hawaii. Pac. Seabird Group Bull. 9(2): 71-72. [Abstract only. Laysan studies briefly described]

Naughton, M. 1984. Trip Report - Laysan Island 22 March - 19 August 1984. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu, HI. 30 pp.

Newman, A. 1984ms. Trip Report: Biological Investigations: Laysan Island, 18 June - 7 August, 1984. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu, HI. [Includes notes on plant distribution and on Laysan Finch feeding habits]

Newman, A. L. 1988. Mapping and Monitoring Vegetation Change on Laysan Island. M.A. thesis, Dept. of Botany, University of Hawaii, December 1988. 234 pp. [Has color vegetation map of Laysan.]

Newton, C. A., and A. J. Chappelle. 1992ms. Trip Report: Laysan Island 18 April - 26 July, 1992. Admin. Rep., U.S. Fish Wildl. Serv., Honolulu, HI. 22 unnumbered pp. [Notes on *Cenchrus* control, annotated lists of vascular plants, breeding birds with Laysan Duck censuses, results of three monthly shorebird counts. Also a few notes on Green Turtles, arthropods, the "dead zone", and lake levels. Notes occurrence of two vagrants, a dead Short-eared Owl collected 1 May and a Cattle Egret seen during the period 5-25 July.]

Nicholson, E. M. 1969. Draft Checklist of Pacific Oceanic Islands. Micronesica 5(2): 327-463. [Brief descriptions of all Pacific islands, work carried out, vegetation, conservation status, etc. Laysan, p. 383.]

N.I.D. (Great Britain Naval Intelligence Division). 1943, Pacific Islands. Vol. II. Eastern Division. London, H.M. Stationery Office. xvi and 739 pp. [Laysan described on pp. 445-446.] [POBSP 224]

Nishida, G. M. (ed.). 1992. Hawaiian terrestrial arthropod checklist. Bishop Mus. Tech. Rep. No. MA-092192. viii and 262 pp. [Lists all terrestrial arthropods known from Laysan (as well as the other Northwestern Hawaiian) islands and provides names according to current taxonomy.]

Nitta, E. T. 1991. The marine mammal stranding network in Hawaii, an overview. Pp. 55-62 *in* John E. Reynolds III and D. K. Odell (eds.). Marine Mammal Strandings in the United States. Proceedings Second Marine Mammal Stranding Workshop, Miami, Florida December 3-5, 1987. NOAA Tech. Rep. NMFS 98. [Lists strandings known from the Hawaiian Islands from 1958 to 1988 including one of *Mesoplodon densirostris* at Laysan in April 1983.]

Nitta, E. T., and J. R. Henderson. 1993. A review of interactions between Hawaii's fisheries and protected species. Mar. Fish. Rev. 55(2): 83-92. [Mentions occurrence, apparently previously unpublished of Rough-toothed Dolphin at French Frigate Shoals, and mentions of other organisms at a variety of Northwestern Hawaiian Islands. Also mentions various Fisheries Management Plans that include restrictions of fishing areas around Laysan and the other Northwestern Hawaiian Islands.]

Nutting, C. C. 1903. Bird rookeries on the island of Laysan. Pop. Sci. Monthly 63: 321-332. [Popular account of Laysan describing bird populations. Photos] POBSP 523]

Nutting, C. C. 1905. Hydroids of the Hawaiian Islands collected by the steamer Albatross in 1902. U.S. Fish. Comm. Bull. 23 (pt. 3): 931-959. [Reports specimens collected offshore Laysan.] [POBSP 1565]

Nutting, C. C. 1908. Descriptions of the Alcyonaria collected by the U.S. Bureau of Fisheries Steamer *Albatross* in the vicinity of the Hawaiian Islands in 1902. Proc. U.S. Nat. Mus. 34 (No. 1624): 543-601. [Reports two new of corals (*Siphonogorgia collaris* (pp. 556-557), and *Pennatula flava* (pp. 558-559) from speciemens collected offshore Laysan. Both are described as new species with the former having its type locality there.] [POBSP 1575]

Oberholser, H. C. 1917. Description of a new genus of Anatidae. Proc. Biol. Soc. Wash. 30: 119-120. [*Horizonetta*, for the genus of the Laysan Duck.] [POBSP 305]

Ohlendorf, H. M., and C. S. Harrison. 1982. Heavy metals and organochlorines in Hawaiian seabird eggs. Pac. Seabird Group Bull. 9(2): 76-77. [Abstract only. Briefly describes results of 1980 fieldwork including samples from Laysan]

Ohlendorf, H. M., and C. S. Harrison, 1986. Mercury, selenium, cadmium and organochlorines in eggs of three Hawaiian seabird species. Environ. Pollution (B) 11: 169-191. [Data from eggs of Wedge-tailed Shearwater, Red-footed Booby, and Sooty Tern collected in 1980 at Manana Island, Oahu; Tern Island, French Frigate Shoals; Laysan and Midway.]

Okamoto, H., and B. Kanenaka. 1984. Preliminary report on the nearshore fishery resource assessment of the Northwestern Hawaiian Islands, 1977-82. Pp. 123-143 *in* R. W. Grigg and K. Y. Tanoue (eds.). Proc. Second Symp. Resour. Invest. Northwest. Hawaiian Islands. UNHIHI-SEAGRANT-MR-84-01. Vol. 1. [Table 2 lists fish species recorded during underwater counts at all the Northwestern Hawaiian Islands; 121 species are listed for Laysan.]

Okamoto, H., and P. Kawamoto. 1980. Progress report on the nearshore fishery resource assessment of the Northwestern Hawaiian Islands: 1977 to 1979. Pp. 71-89 In R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigation in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. in NIHI-Seagrant-MR-8~04. [Includes observations at Nihoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes Reef, Midway and Kure.]

Olsen, D. L. 1969ms a. Hawaiian Islands National Wildlife Refuge Field trip, May

28 - June 11, 1969. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 18 pp.

Olsen, D. L. 1969ms b. Expedition Report, Midway, Lisianski, and Laysan Islands, November 9-13, 1969. Admin. Rep. U. S. Fish Wildl. Serv., Honolulu, HI. 4 pp, 13 pp of pictures. [Not seen; from Hiruki and Ragen 1992]

Olsen, D. L. 1973ms. Expedition Report. Hawaiian Islands National Wildlife Refuge. July 22 - August 1, 1973. Unpubl. Admin. Rep., U. S. Fish. Wildl. Serv., Honolulu, HI. 18 pp. [Visit to Lisianski, Laysan, French Frigate Shoals, Necker and Nihoa. For Laysan, visited 25-27 July, are given an annotated list of birds seen and censuses of endangered species. Collections were made of reef organisms by Leighton Taylor who subsequently made a report entitled "Preliminary Observations of the Inshore Marine Ecosystem on the Leeward Hawaiian Islands".]

Olson, S. L. 1995. History and ornithological journals of the Tanager expedition of 1923 to the Northwestern Hawaiian Islands, Johnston and Wake Islands. Atoll Res. Bull. 433 [In this volume, contains typed copies of the Dickey and Wetmore mss.]

Olson, S. L., and H. F. James. 1986. The holotype of the Laysan Finch *Telespiza cantans* Wilson (Drepanidini). Bull. Br. Ornithol. Club 106(2): 84-86.

Olson, S. L., and A. C. Ziegler. 1995. Remains of land birds from Lisianski Island, with observations on the terrestrial avifauna of the Northwestern Hawaiian Islands. Pacific Sci. 49(2): 111-125. [Documents fossil Laysan Duck from Lisianski with a discussion of the taxonomic status of the land birds that occur or occurred there.]

Ortmann, A. E. 1905. Schizopods of the Hawaiian Islands collected by the Steamer Albatross in 1902. U.S. Fish. Comm. Bull. 23 (pt. 3): 961-974. [Reports single species (*Lophogaster typicus* M. Sars, p. 967) of schizopod from the vicinity of Laysan that was collected by the Albatross Expedition] [POBSP 1566]

Paty, J. 1857. Account of the Manuokawai - Interesting account of her explorations. The Polynesian, 6 June 1857, p. 40. [Notes on early visit to Nihoa, Necker, Gardner Pinnacles, Laysan and Lisianski]

Patzert, W. C. 1973. Current meter data: An indication of either subtropical countercurrent or anticyclonic island circulation. J. Geophys. Res. 78(33): 7919-7922. [Observations 2-5 mi offshore Nihoa, Necker, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes Reef and Midway. Current meters established by USCGS Buttonwood in March, retrieved by R.V. Mahi in May-June 1969.]

Patzert, W. C., K. Wyrtki, and H. J. Santamore. 1970. Current measurements in the central north Pacific Ocean. Rep. HIG-70-31. 65 pp. Hawaii Inst. Geophysics, Honolulu. [More detailed information than is presented in Patzert 1973]

Payne, S. F. 1981. Marine mammals of Hawaii: a bibliography. Lawrence Berkeley Lab., Univ. Calif. 18 pp. [Not seen]

Payne, S. F. 1981. Bibliography of marine turtles in Hawaii. Lawrence Berkeley Lab, Univ. Calif. 9 pp. [Not seen]

Perkins, R. C. L. 1901. An introduction to the study of the Drepanididae, a family of birds peculiar to the Hawaiian Islands. Ibis 8, 1(4): 562-585. [The Laysan Finch is mentioned and keyed out but there is no mention of Laysan other than as island of origin.]

Perkins, R. C. L. 1903. Vertebrata (Aves). In: D. Sharp (ed.) Fauna Hawaiiensis. vol.l. pt.4. pp.368-465.

Perkins, R. C. L. 1906. [List of Midway and Laysan Insects collected by G.P. Wilder]. Proc. Haw. Entomol. Soc. 1(1): 33-34. [Lists 7 species from Laysan, only three identified to species from specimens collected by Wilder in 1905.] [POBSP 590]

Perkins, R. C. L. 1919. A new species of Otiorrhynchine beetle of the genus *Rhyncogonus* Sharp from Laysan Island. Entomol. Mon. Mag. Ser. 3, 49: 4. [POBSP 1604]

Perkins, R. C. L. 1926. Coleoptera, weevils. Pp. 53-66 *in* E. H. Bryan Jr., et al. 1926. [List 7 species from Laysan, all from Fullaway's collections]

Pietrasek, K. J. 1992. Determination of the estrous cycle in the Hawaiian Monk Seal, *Monachus schauinslandi*. M. S. thesis, Univ. Hawaii, Honolulu, 87 pp.

Pietschmann, V. 1938. Hawaiian shore fishes. B. P. Bishop Mus. Bull. 156. 55 pp. [POBSP 1536]

Pilsbry, H. A. 1917. Marine molluscs of Hawaii, IV-VII. Proc. Acad. Nat. Sci. Phila. 69: 309-333. [Describes 3 species from Laysan collected by W. A. Bryan.]

Pilsbry, H. A. 1920. Marine molluscs of Hawaii, VIII-XIII. Proc. Acad. Nat. Sci. Phila. 72: 296-328. [Lists two species from Laysan, one collected by W. A. Bryan, the other by Captain Brown of the U.S. Coast Guard.]

Pilsbry, H. A. 1927. Littoral barnacles of the Hawaiian islands and Japan. Proc. Acad. Nat. Sci. Phila. 79: 305-317. [Lists two species collected by the Tanager Expedition.]

Plehn, M. 1899. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1896-97). Polycladen. Zool. Jahrb. Syst., 12: 448-452. [Describes a new genus and species of turbellarian from Laysan: *Microscelis schauinslandi* (pp. 449-450)] [POBSP 1596]

Polovina, J. J., 1989. Density dependence in spiny lobster, *Panulirus marginatus*, in the Northwestern Hawaiian Islands. Can. J. Fish. Aquat. Sci. 46: 660-665. [Data for Necker, Gardner Pinnacles, Raita Bank, Maro Reef, Pearl and Hermes Reef, Midway and Laysan, the latter sampled in 1977.]

Powell, A. W. B. 1967. The family Turridae in the Indo-Pacific. Part 1a. The subfamily Turrinae concluded. Indo-Pacific Mollusca 1(7): 409-444. [Describes (p. 435) *Gemmula interpolata* sp nov. from Laysan from the Albatross collections]

Pratt. H. D., P.L. Bruner, and D. G. Berrett. 1987. A Field Guide to the Birds of Hawaii and the Tropical Pacific. Princeton University Press, Princeton, NJ. 409 pp, 45 pls. [Describes and illustrates all birds on Laysan, including extinct rail.]

Pratt, T. K. 1987. Recent observations. March through May 1987. ‘Elepaio 47(9): 93-95. [Same information for Laysan as Pyle 1987a.]

Pratt, T. K. 1988a. Recent observations. August through November 1987. ‘Elepaio 48(3): 21-22, 48(4): 30-31. [Same information for Laysan as Pyle 1988a.]

Pratt, T. K. 1988b. Recent observations. March - May 1988. ‘Elepaio 48(8): 65-66, 48(9): 77-78. [Reports count of Laysan Duck and sighting of Bar-tailed Godwits at Laysan; other observations as in Pyle 1988b]

Preiwisch, J. 1903. Kalkschwämme aus dem Pacific. Ergebnisse einer Reise nach dem Pacific, Schauinsland 1896/97. Zool. Jahrb., Syst. 19: 9-26. [Records 2 species of calcareous sponges from Laysan, both described as new species: *Sycandra parvula* and *Sycandra staurifera*] [POBSP 1584]

Pyle, P., and B. Eilerts. 1986. Pelagic seabird observations from Northwest Hawaiian Island waters. ‘Elepaio 46: 181-183. [Numerous seabirds mentioned from Laysan; Wilson’s Petrel (*Oceanites oceanicus*) near Laysan is new for Hawaiian waters.]

Pyle, R. L. 1978. Recent observations of birds August to November [1977]. ‘Elepaio 38(9): 101-106. [Same information for Laysan as Ralph and Pyle 1978.]

Pyle, R. L. 1979. Hawaii bird observations August 1978 through February 1979. ‘Elepaio 40(1): 13-16, 40(2): 28-30. [Same report as in Pyle and Ralph, adding that the Least Tern "in fine plumage" was seen "at close range"]

Pyle, R. L. 1980. Hawaii bird observations March through July 1979. ‘Elepaio 41(6): 46-49. [Reports count of Laysan Duck and Bristle-thighed Curlews, Sharp-tailed Sandpipers, Pectoral Sandpiper, and Bar-tailed Godwits on Laysan]

Pyle, R. L. 1981. Hawaii bird observations August 1979 through July 1980.

'Elepaio 41(8): 72-79. [Notes presence of Cattle Egret (*Bubulcus ibis*), European Wigeon (*Anas penelope*), and Lesser Yellowlegs on Laysan.]

Pyle, R. L. 1983. The nesting season. June 1 - July 31, 1983. Hawaiian Islands Region. Am. Birds 37(6): 1028-1029. [Notes the appearance of three Hawaiian Coots, (*Fulica americana alai*) at Laysan.]

Pyle, R. L. 1985a. The autumn migration. August 1 - November 30, 1984. Hawaiian Islands Region. Am. Birds 39(1): 105-107. [Provides a count of over 7000 shorebirds at Laysan 7 November, and includes reports of the uncommon Green-winged Teal, (*Anas crecca carolinensis*) (5), Lesser Yellowlegs (1), Bar-tailed Godwit (3), Pectoral Sandpiper (l), Sharp-tailed Sandpiper (1), Dunlin (1), Ruff (1), Short-billed (1), and Long-billed (2) dowitchers.]

Pyle, R. L. 1985b. The spring migration. March 1 - May 31, 1985. Hawaiian Islands Region. Am. Birds 39(3): 351-353. [Reports counts for Sooty Storm-Petrels (*Oceanodroma tristrami*) at colony at NW end of the lagoon, a report on numbers of Laysan Duck and numbers for shorebirds seen during three days in late April, the latter including Bar-tailed Godwits. Also reports the occurrence of the Short-eared Owl (*Asio flammeus*) the first report for the atoll.]

Pyle, R. L. 1985ms. Migratory bird counts. Laysan Island --- April 1985. Unpubl. Rep. in files of the U. S. Fish Wildl. Serv., Honolulu, HI. 13 pp. [Detailed counts 3, 6, 9 April along the lagoon, at the southwestern rock ledge, and along the beach.]

Pyle, R. L. 1986a. The spring migration. March 1 - May 31, 1986. Hawaiian Islands Region. Am. Birds 40(3): 526-527. [Reports presence of Asiatic Whimbrel (*Numenius phaeopus variegatus*), dowitchers, Dunlin, and Bar-tailed Godwit at Laysan]

Pyle, R. L. 1986b. Recent observations. March - June 1986. 'Elepaio 46(14): 156-157. [Information for Laysan as in Pyle 1986a.]

Pyle, R. L. 1986c. The nesting season. June 1 - July 31, 1986. Hawaiian Islands Region. Am. Birds 40(5): 1257-1258. [Reports Least or Little Tern (*Sterna antillarum/albifrons*) at Laysan for a week beginning 10 July as well as a sighting of a Red-necked Phalarope]

Pyle, R. L. 1986d. Recent observations. June-July 1986. 'Elepaio 46(16): 175-176. [Information for Laysan as in Pyle 1986b.]

Pyle, R. L. 1987. The spring migration. March 1 - May 31, 1987. Hawaiian Islands Region. Am. Birds 41(3): 491-493. [Mention of delayed nesting cycle in Laysan Finches possibly because of unfavorable winter weather.]

Pyle, R. L. 1988a. The autumn migration. August 1 - November 30, 1987. Hawaiian Islands Region. Am. Birds 42(1): 140-142. [Laysan Ducks said to have poor breeding season with no ducklings surviving because of drought reducing the brine fly population.]

Pyle, R. L. 1988b. The spring season. March 1 - May 31, 1988. Hawaiian Islands Region. Am. Birds 42(3): 484-485. [Rough-legged Hawk (*Buteo lagopus*) seen at Laysan is the first record for the island and the state of Hawaii; also provides a few remarks on Bristle-thighed Curlew populations and the first sighting for the atoll of Franklin's Gull (*Larus pipixcan*).]

Pyle, R. L. 1989. The autumn migration. August 1 - November 30, 1988. Hawaiian Islands Region. Am. Birds 43(1): 172-174. [Reports Cattle Egrets, Green-winged Teal, Garganeys (*Anas strepera*), Common Goldeneye (*Bucephala clangula*), Hawaiian Coot, Sharp-tailed Sandpipers, Spotted Sandpiper (*Actitis macularia*), Ruff, Red-necked Phalarope and Short-eared Owl at Laysan, the Goldeneye only the 2nd record for the Hawaiian Islands; the Coot the first record for Laysan and the Spotted Sandpiper the first record for the Northwestern Hawaiian Islands; also provides some remarks on Bristle-thighed Curlews including the recapture of a bird that had been banded in the Yukon Delta, Alaska.]

Pyle, R. L. 1990a. The autumn migration. August 1 - November 30, 1989. Hawaiian Islands Region. Am. Birds 44(1): 166-168. [Streaked Shearwater (*Calonectris leucomelas*) reported (with 1/3 page photo) at Laysan, the first well documented record for the Hawaiian Islands, cf Marks ; also notes summering population of over 100 Bristle-thighed Curlews and a Whimbrel that was banded and released.]

Pyle, R. L. 1990b. The nesting season. June 1 - July 31, 1990. Hawaiian Islands Region. Am. Birds 44(5): 1189-1190. [Report a Bristle-thighed Curlews on Oahu that had been color-banded at Laysan.]

Pyle, R. L. 1991a. The autumn migration. August 1 - November 30, 1990. Hawaiian Islands Region. Am. Birds 45(1): 155-156. [Notes presence of Garganey, European Wigeon, Bufflehead, Northern Harrier (*Circus cyaneus*), Whimbrel, Pectoral and Sharp-tailed Sandpipers, Common Snipe (*Capella gallinago*) and Ruff at Laysan; the Harrier being the first record for Laysan and one of the very few records for Hawaii. The color-banded Bristle-thighed Curlew seen on Oahu (see above) was seen again on Laysan.]

Pyle, R. L. 1991b. The summer season. June 1 - July 31, 1991. Hawaiian Islands Region. Am. Birds 45(5): 1163-1164. [Franklin's Gull reported present at Laysan]

Pyle, R. L. 1992a. The autumn migration. August 1 - November 30, 1991. Hawaiian Islands Region. Am. Birds 46(1): 153-155. [Notes a color-banded Bristle-

thighed Curlew in Oahu that had been banded on Laysan in October 1988]

Pyle, R. L. 1992b. The spring season. March 1 - May 31, 1992. Hawaiian Islands Region. Am. Birds 46(3): 483-485. [Reports Red Phalaropes (*Phalaropus fulicaria*), Herring Gull (*Larus argentatus*), and a Short-eared Owl from Laysan, the latter later found dead and preserved as a specimen.]

Pyle, R. L. 1993a. The autumn migration. August 1 - November 30, 1992. Am. Birds 47(1): 152-154. [Seen at Laysan were Bar-tailed Godwit(s?), Ruff, Red-necked Phalarope, Red Phalarope and Great Crested Tern; the latter previously unrecorded from the island.]

Pyle, R. L. 1993b. The winter season. December 1, 1992 - February 28, 1993. Am. Birds 47(2): 302-304. [Cattle Egret and Bufflehead seen on Laysan]

Pyle, R. L. 1993c. The spring season. March 1 - May 28, 1993. Am. Birds 47(3): 455-456. [Single female-plumaged Green-winged Teal, American Widgeon (*Anas americana*), and Bufflehead reported at Laysan]

Pyle, R. L. 1993d. The summer season. June 1-July 31, 1993. Hawaiian Islands Region. Am. Birds 47(5): 1152-1153. [Notes failure of Laysan Duck to fledge any young in 1993.]

Pyle, R. L. 1994. The autumn migration. August 1 - November 30, 1993. Hawaiian Islands Region. Am. Birds 48(l): 155-156. [Mentions Cook's Petrel (*Pterodroma cookii*) offshore Laysan and Garganey and Pintails on the island.]

Pyle, R. L. 1995a. Fall Season. August 1 - November 1, 1994. Hawaiian Islands Region. Natl. Aud. Soc. Field Notes 49(1): 104-105. [Seen at Laysan were one Cattle Egret 14 September and three by 2 November, a European Widgeon 3 October - 3 November a Whimbrel 1 November, Sharp-tailed Sandpipers (eight seen 25 September, 12 in mid October, a Curlew Sandpiper (*Calidris ferruginea* - one well described and photographed) 1 October, a Red-necked Phalarope and a Red Phalarope together 18 October, and a Glaucous-winged Gull (*Larus glaucescens*) in the last week or so of November.]

Pyle, R. L. 1995b. Winter Season. December 1, 1994 - February 28, 1995. Hawaiian Islands Region. Natl. Aud. Soc. Field Notes 49(2): 203-204. [Seven Cattle Egrets seen at Laysan during the winter; also reported there were a Peregrine Falcon (*Falco peregrinus*) 31 December-9 January that had preyed upon Black Noddy and Laysan Finch, a Pomarine Jaeger (*Stercorarius pomarinus*) 24 December that was feeding on a Bonin Petrel (*Pterodroma hypoleuca*), a first winter Glaucous-winged Gull 15 November-3 March, and a Black Tern (*Chlidonias niger*) 21-31 December and 11 January-8 March; neither jaeger nor tern, the latter rare in the tropical Pacific had previously been reported from Laysan.]

Pyle, R. L., and C. J. Ralph. 1979. The autumn migration. August 1 - November 30, 1978. Hawaiian Islands Region. Am. Birds 33(2): 218-220. [Reports sighting of Least Tern (*Sterna albifrons*) at Laysan]

Pyle, R. L., and C. J. Ralph. 1979. The spring migration. March 1 - May 31, 1979. Hawaiian Islands Region. Am. Birds 33(5): 807-808. [Reports 3 winter-plumaged Bar-tailed Godwits (*Limosa lapponica*) at Laysan.]

Pyle, R. L., and C. J. Ralph. 1980a. The autumn migration. August 1 - November 30, 1979. Hawaiian Islands Region. Am. Birds 34(2): 204-205. [Reports the presence of a European Widgeon (*Anas penelope*) on Laysan.]

Pyle, R. L., and C. J. Ralph. 1980b. The spring migration. March 1 - May 31, 1980. Hawaiian Islands Region. Am. Birds 34(5): 817-818. [Report's the presence of an immature Laughing or Franklin's Gull (*Larus atricilla/pipixcan*) but provides no details.]

Ragen, T. J. 1993. Status of the Hawaiian Monk Seal in 1992. Southwest. Fish. Cent. Honolulu Lab., NMFS, NOAA, Honolulu HI. 96822-2396. SWFC Admin. Rep. H-93-05. 79 pp. [Population studies since the 1950s tabulated and discussed.]

Ragen, T. J. 1994. Preliminary results of 1994 Hawaiian Monk Seal Field Studies. Southwest Fish. Sci. Cent. Rep. Activities, October-December 1994: 4-6. [Data from March - August 1994 field work on Laysan]

Ralph, C. J., and R. L. Pyle. 1978. The fall migration. August 1 - November 30, 1977. Hawaiian Islands Region. Am. Birds 32(2): 265-267. [Reports the occurrence of a Cattle Egret at Laysan]

Randall, J. E. 1956. A revision of the surgeon fish genus *Acanthurus*. Pacific Sci. 10(2): 159-235. [Revises taxonomy used in Fowler 1928 and other sources. The only species specifically mentioned as occurring at Laysan are *Acanthurus triostegus* Linnaeus and *A. nigriloris* Cuvier and Valenciennes.]

Randall, J. E. 1983. A review of the fishes of the subgenus *Goniistius*, genus *Chedilodactylus*, with description of a new species from Easter Island and Rapa. B. P. Bishop Mus. Occ. Pap. 25(7): 1-24. [Shows that *Gregorina gygis* (described from Laysan as new species by Fowler and Ball) is a late postlarval stage of *Chedilodactylus vittatus*.]

Rathbun, M. J. 1906. The Brachyura and Macrura of the Hawaiian Islands. U.S. Fish. Comm. Bull. 23 (pt. 3): 827-930. [Reports specimens collected at Laysan by the Albatross Expedition.] [POBSP 1564]

Rauzon, M. J. 1979ms. Survey of the Hawaiian Monk Seal (Monachus

schauinslandi) Northwestern Hawaiian Isles, 9-25 May 1979. Anchorage, AK, Natl. Fish. Wildl. Lab. 8pp. [Not seen; from Hiruki and Ragen 1992]

Rauzon, M. J. 1981ms. Review of the Hawaiian Monk Seal aerial census. U. S. Fish Wildl. Serv. 9 pp. [Not seen; from Hiruki and Ragen 1992]

Rauzon, M. J., C. S. Harrison, and S. Conant. 1985. The status of the Sooty Storm Petrel in Hawaii. Wilson Bull. 97(3): 390-392. [Observations on Nihoa, Necker, French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes Reef, and Midway.]

Reinbold, T. 1899. Meeresalgen. Ergebnisse einer Reise nach dem Pacific, H. Schauinsland 1896-97. Abh. Nat. Ver. Bremen 16: 287-302. [Reports *Sargassum polyphyllum* J. Ag. from Laysan].

Reynolds, J. N. 1835. ...A report of J.N. Reynolds, in relation to islands, reefs, and shoals in the Pacific Ocean, Sc. Document No. 105, U.S. House of Rep., 23rd Congress, and Session. Vol. 3: i-28.

Rhumbler, L. 1906. Foraminiferen von Laysan und den Chatham-Inseln. Ergebnisse einer Reise nach dem Pacific, Schauinsland 1896-97. Zool. Jahrb. Syst. 24: 21-80. [Reports 39 species from Laysan from specimens collected by Schauinsland; 9 of these are described as new species: *Hyperammina calcilega*, *Tubinella perforata*, *Nodobacularia irregularis*, *Miliolina schauinslandi*, *M. deplanata*, *M. arenacea*, *M. ferox*, *M. cribrostoma*, *Adelosina laysanensis*] [POBSP 1583]

Rice, D. W. 1960a. Population dynamics of the Hawaiian monk seal. J. Mammal. 41(3): 376-385. [Data from surveys 1956-1958 of Kure, Midway, Pearl and Hermes Reef, Lisianski, Laysan and French Frigate Shoals with ground observations at Laysan 27 May to 4 June 1958] [POBSP 20]

Rice, D. W. 1960b. Distribution of the bottle-nosed dolphin in the Leeward Hawaiian Islands. J. Mammal. 41(3): 4O7-408. [Half-a dozen *Tursiops truncatus* recorded ca. 3 km southeast Laysan on 27 May 1958] [POBSP 1580]

Rice, D. W. 1964. The Hawaiian Monk Seal. Natural History 73: 48-55. [POBSP 1326]

Rice, D. W. 1990ms. Memorandum to R. L. DeLong, 29 December 1990: monk seal counts for Laysan, Lisianski and Pearl & Hermes Reef. 1957-58. In L. L. Eberhardt, Reconstructing population trends of the Hawaiian Monk Seal. 14 pp. [Not seen; from Hiruki and Ragen 1992]

Rice, D. W., and K. W. Kenyon, 1962. Breeding distribution, history, and populations of North Pacific albatrosses. Auk 79(3): 365-386. [POBSP 977]

Rice, D. W., and K. W. Kenyon 1962. Breeding cycles and behavior of Laysan and Black-footed albatrosses. Auk 79(4): 517-567. [POBSP 978]

Riotte, J. C. E. 1991. Reassessment of the Noctuoidea of the Hawaiian Islands. B. P. Bishop Mus. Occ. Pap. 31: 139-151. [Records include some for Necker, Nihoa, French Frigate Shoals, Kure, Lisianski, Laysan, Midway, Johnston Island, Pearl and Hermes Reef. Some records presumably represent new distributional records but it is not clear which are from the way the paper is written.]

Ripley, [S]. D. 1959. Laysan Teal at Litchfield. Avic. Mag. 65: 172-174. [Minor mention of birds taken from Laysan to several zoos in 1957 and 1959; provides breeding data at his Litchfield, CT aviary.]

Ripley, S. D. 1960. Laysan Teal in captivity. Wilson Bull. 72(3): 244-247. [Notes on birds brought from Laysan; observations of adults and of young hatched in captivity led author to conclude that the Laysan Teal was distinct species. Figure 1 shows the distinctive plumage pattern of the downy young.] [POBSP 1000]

Ripley, S. D. 1985. The Laysan Teal -- recent history and future? Avic. Mag. 91(1-2): 76-78.

Roach, F. L. 1961. East Pacific Survey Phase I, U.S.S. Duval County LST 758. (Typescript copy of report in the files of the 14th Naval District, Honolulu). [Reports mission to establish first order astronomic stations and HIRAN and Azmuth marks on the Northwestern Hawaiian Islands, the survey of Laysan occurring 12-20 March 1961] [POBSP 1706]

Robbins, C. S., and D. W. Rice. 1974. Recoveries of banded Laysan Albatrosses (*Diomedea immutabilis*) and Black-footed Albatrosses (*D. nigripes*). Pp. 232-271 *in* W. B. King (ed.). Pelagic studies of seabirds in the Central and Eastern Pacific Ocean. Smithsonian Contr. Zool. No. 158.

Rock, J. F. 1916. The sandlewoods of Hawaii. Hawaii Bd. Agr. and For., Bot. Bull. 3: 1-43. [Describes (p. 39) sandlewood on Laysan as a new variety, *Santalum cuneatum laysanicum*, from collections by Schauinsland, W. A. Bryan, and Fullaway] [POBSP 429]

Rogers, W. J., and R. Schauffler. 1993. Trip Report: Laysan Island 09 November 1992 - 17 March 1993. Admin. Rep. U. S. Fish Wildl. Serv., Honolulu, HI. 31 pp.

Rollin, S. 1989. Le phoque moine de Hawaii (*Monachus schauinslandi*). Histoire naturelle et conservation de l'espece. These Veterinaire, Univ. Claude Bernard de Lyon. 177 pp. [Includes includes remarks on the seal at Laysan]

Rosane, D. 1992. Thérapie de choc pour phoques déchaines. Terre Sauvage 67:

90-99. [Richly illustrated magazine article about a seal study trip to Laysan with W. G. Gilmartin.]

Rosewater, J. 1970. The family Littorinidae in the Indo-Pacific. Part I. The subfamily Littorininae. Indo-Pacific Mollusca 2(11): 417-506. [From Laysan records *Littorina p. pintado* (Wood 1928)(p. 449), *Nodilittorina picta* (Philippi, 1846)(p. 504)]

Ross, E. S. 1951. A new species of Embioptera from Oceania. Proc. Haw. Entomol. Soc. 14(2): 307-310. [*Oligotoma* (*Aposthonia*) *oceania* sp. nov.; includes specimens from Laysan earlier identified as *0. insularis* by Bryan (1926)] [POBSP 203]

Rothschild, W. 1892a. [Description of *Anas laysanensis*]. Bull. Brit. Ornith. Club 1: xviii.

Rothschild, W. 1892b. Descriptions of seven new species of birds from the Sandwich Islands. Ann. Mag. Nat. Hist. (ser. 6) 10: 108-112. [Includes another description of *Anas laysanensis*] [POBSP 335]

Rothschild, W. 1893a. [Original description of *Diomedea immutabilis* from Laysan]. Bull. Brit. Ornith. Club 1: 48.

Rothschild, W. 1893b. [*Anas laysanensis*, sp. n.]. lbis 6,5: 249-250. [POBSP 990] [cf 1108]

Rothschild, W. 1893c. [*Diomedea immutabilis*, sp. n.] lbis 6,5: 448. [POBSP 991]

Rothschild, W. 1893-1900. The avifauna of Laysan and the neighboring islands... London, R.H. Porter. 3 parts, xx and 320 pp. [POBSP 1027]

Rothschild, W. 1894. Some new species of Lepidoptera. Novit. Zool. l: 535-540. [Lists three species from Laysan, one, *Prodenia laysanensis*, described as new.] Another, a Noctuid, *Peridroma* [= *Agrotis*] *evanescens*, described from Midway, is otherwise now only known from Laysan ?] [POBSP 1609]

Rowland, C. M. 1991ms. Trip report: Laysan, June 24 - August 7, 1991. Admin. Rep., U. S. Fish and Wildl. Service, Honolulu, HI. 5 pp (and 9 unnumbered pp of data and notes). [Report of visit to Laysan 30 June-30 July. Remarks on alien (*Cenchrus*, *Nicotiana*, *Cynodon*) and endemic (*Nama sandwicensis*) plant distribution and censuses booby (also mapped) and Laysan Finch populations.]

Saito, Y. 1969. The algal genus *Laurencia* from Hawaii and the Philippines. Pacific Sci. 23: 148-160. [Reports four species from Laysan identifying and reidentifying collections made by Tsuda in December 1963] [POBSP 1620]

Salisbury, G. R. (ms.). Report on Laysan Expedition, December 5, 1912 to April 11, 1913. Rec. Group 22, U.S. Natl. Arch. 8 pp. [Notes conditions on island, planting of 100 Coconut (*Cocos nucifera*) sprouts, and spread of tobacco plants. Also gives nest counts for Laysan and Black-footed Albatross, Black Tern and Great Frigatebird, and states that only four guinea pigs (*Cavia porcellus*) were seen, all of which were killed. 83 Laysan Rails taken for zoos but most died en route.] [POBSP 1550]

Sanger, G. A. 1974. Black-footed Albatross (*Diomedea nigripes*), pp. 96-128 in W. B. King (ed.). Pelagic Studies of Seabirds in the Central and Eastern Pacific Ocean, Smithsonian Contrib. Zoology 158. [Pelagic range maps and sightings, including waters around Laysan].

Sanger, G. A. 1974. Laysan Albatross (*Diomedea immutabilis*). Pp. 129-153 in W. B. King (ed.). Pelagic Studies of Seabirds in the Central and Eastern Pacific Ocean, Smithsonian Contrib. Zoology 158. [Pelagic range maps and sightings, including waters around Laysan].

Sars, G. O. 1903. Pacifische Plankton-Crustaceen. (Ergebnisse einer Reise nach dem Pacific, Schauinsland 1896/97). Zool. Jahrb., Syst. 19: 629-646. [Reports on brine shrimp (*Artemia salina* (Lin.) var. *pacifica* G. O. Sars)(pp. 630-631) found at Laysan.] [POBSP 1597]

Schauffler, R., and W. J. Rogers, Jr. 1993ms. Trip Report: Laysan Island 09 November 1992 - 17 March 1993. Admin. Rep. U.S. Fish Wildl. Serv., Honolulu, HI. 32 unnumbered pp. [Data on *Cenchrus* control, estimates of nesting Laysan and Black-footed albatrosses from transect counts, an annotated list of breeding birds including numerous Laysan Duck counts, annotated list of vascular plants, notes on the "dead zone" and a map of Black Noddy colonies.]

Schauinsland, H. 1899a. Drei Monate auf einer Korallen-Insel (Laysan). Bremen, Nössler. 104 pp. [Account of a major scientific expedition in 1896 with results appearing or commented upon in dozens of papers included herein. For English translation see Udvardy 1995.] [521]

Schauinsland, H. H. 1899b. Das Vogelleben auf der Insel Laysan. Ornithol. Monatsberichte 7: 121-126, 144-150. [Condensed from Schauinsland 1899a] [POBSP 521, original and English translation]

Schilder, F. A. 1933. Cypraeacea from Hawaii. B. P. Bishop Mus. Occ. Papers 10(3): 1-22. [Reports 8 species collected on Laysan 1 March 1928: *Mauritia scurra* Gmelin, *Talparia talpa* Linnaeus, *Basilitrona isabella* Linnaeus, *Lyncina sulcidentata* Gray, *Pustularia tessellata* Swainson, *Ravitrona caputanguis* Philippi, *Erosaria helvola* (Linnaeus) *hawaiiensis* Melville, *Staphylaea semiplota* Mighels]

Schindler, O. 1932. Sexually mature larval Hemiramphidae from the Hawaiian

Islands. B. P. Bishop Mus. Bull. 97. pp. 28. [POBSP 1532]

Schlemmer, M. and E. L. Schlemmer. (ms.). Copy of the log of the yacht "Helene" and diary written on Laysan Island from June 25 to December 2, 1915. Rec. Group 22, U.S. Nat. Arch. (original in possession of E.L. Schlemmer). 32 pp. [POBSP 1550]

Schreiber, R. W., and E. Kridler. 1969. Occurrence of an Hawaiian Monk Seal (*Monachus schauinslandi*) on Johnston Atoll, Pacific Ocean. J. Mammal. 50: 841-842. [Animal tagged as a pup on Laysan 18 March 1968 seen at Johnston Atoll from the last week of July through 31 October 1968.]

Schlanger, S. O., and G. W. Gillett. 1976. A geological perspective of the upland biota of Laysan Atoll, Hawaiian Islands. Biol. J. Linnean Soc. 8(3): 205-216.

Schreiber, E. A., and R. W. Schreiber. 1993. Red-tailed Tropicbird (*Phaethon rubricauda*). (A. Poole and F. Gill, eds.) The Birds of North America No. 43: 24 pp. [Account summarizing distribution and natural history makes a few secondary mentions of Laysan. Most of the information presented is based on work at Kure, Johnston, and Christmas atolls, much of that for the latter two previously unpublished.]

Scott, J. M., and C. B. Kepler. 1985. Distribution and abundance of Hawaiian native birds: a status report. Bird Conserv. 2: 43-71. [Remarks on Laysan Duck (p. 47), Laysan Rail (p. 48) and Laysan Finch (p. 54)]

Scott, J. M., C. B. Kepler, C. van Riper III, and S. I. Fefer. 1988. Conservation of Hawaii's vanishing avifauna. BioScience 39(4): 239-253. [Minor mention of Laysan Duck, Laysan Finch. Derivative.)

Seki, M. P. 1984. The food and feeding habits of the White Trevally, *Pseudocaranx dentex* (Block and Schneider 1801), in the Northwestern Hawaiian Islands. Pp. 192-208 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-01. Vol. 2. [Based on stomach samples collected at Nihoa (3), French Frigate Shoals (3), St. Rogatien Bank (7), Gardner Pinnacles (9), Raita Bank (8), Maro Reef (5), Laysan (4), Pioneer Bank (1), Bank No 9 (3), Pearl and Hermes Reef (15) and Kure (5). No information is given for specific localities.]

Sekora, P. C. 1975ms. Expedition report. Hawaiian Islands National Wildlife Refuge. August 4-16, 1975. Unpubl. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu, HI. 7 pp. [Nihoa, Necker, Laysan, and Lisianski visited. For Laysan, visited 9-12 August, are given crude estimates of bird populations and more detailed census data for Hawaiian Monk Seal, Laysan Duck and Laysan Finch. Also on the expedition were two members of the National Geographic Society and the British Broadcasting Company.]

Sekora, P. C. 1975. Refuge for rare species. Defenders 50(6): 506-511. [Mention of all islands in minor way; gives population estimates for Laysan Duck and Laysan Finch and photograph of former.]

Sekora, P. C. 1976ms. Expedition report. Hawaiian Islands National Wildlife Refuge. August 17-28, 1976. Unpubl. Admin. Rep., U. S. Fish Wildl. Serv., Honolulu, HI. 7 pp. [Nihoa, Necker, French Frigate Shoals, and Laysan visited. For Laysan, visited 22-26 August are given crude estimates of bird populations and more detailed census data for Hawaiian Monk Seal, Laysan Duck and Laysan Finch. Also on the expedition were Marlin Perkins and two other employees of Wild Kingdom who spent much time photographing the island. Oiling of the beaches was also noted.]

Sekora, P. C. 1978. Report of Short-tailed Albatross from Hawaiian Is. Misc. Rep. Yarnashina Inst. Ornithol. 9(1): 15-58. [Includes a sight record from Laysan]

Shallenberger, E. W. 1982. A seal slips away. Nat. Hist. 91(12): 48-53. [Derivative, but some mention of Laysan with comments on 1978 ciguatera poisoning.]

Shallenberger, R. J. 1977. Regional Report VIII. Hawaii. Pac. Seabird Group Bull. 4(2): 8-10. [Laysan field studies briefly described]

Shallenberger, R. J., W. Perryman, and M. Rauzon. 1982ms. Monitoring Hawaiian Monk Seals with aerial photography. Poster presented at 1982 Marine Mammal Meetings. [Report available from the U. S. Fish and Wildlife Service, Refuges and Wildlife Resources, Honolulu, HI; not seen, from Newman 1988]

Shannon, R. C. 1926. A new *Lucilia* from Hawaii. P. 72 *in* E. H. Bryan et al. 1926. [Calliphorid fly, *Lucilia graphita* sp. nov., raised from seal skull from Laysan]

Sibley, F. C. 1964ms. Preliminary report on ATF trip No. l, February-March 1963. POBSP unpublished ms., Smithsonian Institution, Washington DC. 13 pp. [SIA 245, Ser. 37, 163, 7]

Sibley, F. C. and R. W. McFarlane. 1968. Gulls in the Central Pacific. Pacific Sci. 22(3): 314-321. [Lists a specimen of Herring Gull taken at Laysan 12 February 1963] [POBSP 1659]

Sileo, L., P. R. Sievert, M. D. Samuel, and S. I. Fefer. 1990. Prevalence and characteristics of plastic ingested by Hawaiian seabirds. Pp. 665-681 in R. S. Shomura and M. L. Godfrey (eds.). Proc. Second Internatl. Conf. Marine Debris, 2-7 April 1989. NOAA Tech. Mem. NMFS 154. [Based on stomach samples collected on Kauai, Nihoa, Tern Island, French Frigate Shoals, Pearl and Hermes Reef, Johnston Atoll and and Laysan Island. A table lists details by specimen from site to site.]

Simon, E. 1898. Descriptions d'Arachnides nouveaux des familles des Agelenidae,

Pisauridae, Lycosidae et Oxypodidae. Ann. Soc. Entomol. Belgique 42: 5-34. [Describes *Lycosa* (*Alopecosa*) *stygialis* (= *Lycosa oahuensis*) attributing their origin to the Hawaiian Islands and only later making it clear that the spider had been collected on Laysan]

Simon E. 1899. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1896-97). Arachnoideen. Zool. Jahrb., Syst. 12: 411-437. [Describes pseudoscorpion *Lophochernes laysanensis* (p. 414), perhaps endemic to Laysan, and lists 5 other species collected by Schauinsland.] [POBSP 1595]

Sincock, J. L. 1974ms. Periodic Activity Report, Northwestern Hawaiian Islands. July 13-August 14, 1974. Admin. Rep., U. S. Fish Wildl. Serv. 7 pp. [Not seen; from Hiruki and Ragen 1992]

Sincock, J. 1975ms. Annual Research Progress Report, 1975: Population surveys of endangered species of the Hawaiian Leeward Islnds. U. S. Dep. Interior, U. S. Fish Wildl. Serv. 4 pp. [Not seen; from Hiruki and Ragen 1992]

Sincock, J., and E. Kridler. 1968ms. Vegetative cover map of Laysan Island, September 8, 1968. Bureau of Sport Fisheries and Wildlife, Honolulu, HI. [Not seen, from Newman 1988]

Sincock, J. L., and E. Kridler. 1977ms. The extinct and endangered endemic birds of the Northwestern Hawaiian Islands. U.S. Fish and Wildlife Service, Honolulu, Hawaii. 111 pp.

Sincock, J., E. Kridler, and P. Sekora. 1974ms. Annual Research Progress Report, 1974: Population surveys of endangered birds of the Hawaiian Leeward Islands. U. S. Dep. Interior, U. S. Fish Wildl. Serv. 4 pp. [Not seen; from Hiruki and Ragen 1992]

Sluiter, C. P. 1900. Tunicaten aus dem Stillen Ocean. Ergebnisse einer Reise nach dem Pacific. (Schauinsland 1896-97). Zool. Jahrb., Syst. 13: 1-35. [Reports 6 species from Laysan describing four as new species: *Ecteinascidia diligens* (pp. 3-4), *Distoma parva* (p. 6), *D. fusca* (p. 7-8), and *D. laysani* (p. 9-10)] [POBSP 1593]

Smythe, W. R. 1960. Monk seals on Laysan Island. 'Elepaio 20(11): 78-79. [General observations during 3-day visit in April 1959] [POBSP 881]

Snyder, J. O. 1904. A catalogue of the shore fishes collected by the steamer Albatross about the Hawaiian Islands in 1902. U.S. Fish. Comm. Bull. 22: 513-538. [POBSP 1569]

Snyder, J. O. 1917. Notes on Hawaiian lizards. Proc. U.S. Nat. Mus. 54 (No. 2224): 19-25. [Reports, pp. 23, 25, collections and observations of two species of lizards (*Hemidactylus garnottii*, *Ablepharus poecilopleurus*) on Laysan in May 1902]

[POBSP 365]

Speiser, P. 1902. Studien über *Diptera pupipara*. Zeitschr. Syst. Hym. Dipt. 2: 145-180. [Reports a hippoboscid fly from collections made by Schauinsland] [POBSP 1639]

Spengel, J. W. 1903. Neue Beitrage zu Kenntniss der Enteropneusten. 1. *Phychodera flava* Eschsch. von Laysan. (Ergebnisse einer Reise nach dem Pacific (Schauinsland 1896-97]). Zool. Jahrb. Anat. 18: 271-326.

Stadel, D. L. 1967ms. Preliminary report, Laysan Island, Leeward Island survey 19, June 7-12, 1967. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 18 pp. [Notes and estimates for 24 species of birds with map showing nesting areas of Sooty Terns and tables giving culmen measurements for both species of albatross, plant associations and nesting materials for Brown Noddies, egg measurements for Red-footed Boobies, Great Frigatebirds, and Common Noddies, and totals banded and returned] [POBSP BB 8/SIA 37, 163, 19]

Starbuck, A. 1878. History of the American whale fishery from its earliest inception to the year 1876. Pp. 1-779 *in* Report of the Commissioner of Fish and Fisheries for 1875-1876. Washington Government Printing Off.

Starfield, A. M., J. D. Roth, and K. Ralls. "Mobbing" in Hawaiian Monk Seals (*Monachus schauinslandi*): the value of simulation modeling in the absence of apparently crucial data. Conserv. Biol. 9(1): 166-174. [Model simulates situation on Laysan where mobbing may limit population growth and is based on data collected largely at Laysan.]

Steele, C. W. 1965. Fungus populations in marine waters and coastal sands of the Hawaiian, Line, and Phoenix Islands. M.S. thesis, University of Hawaii, Honolulu, HI. [Not seen]

Steele, C. W. 1967. Fungus populations in marine waters and coastal sands of the Hawaiian, Line and Phoenix Islands. Pacific Sci. 21(3): 317-331. [Correction in Pacific Sci. 32(4): 560, 1968) [Based in part on samples obtained on Kure, Midway, Pearl and Hermes Reef, Lisianski, Laysan, and French Frigate Shoals. Almost none of the identifications reported are identified to specific site or collection date.] [POBSP 1802].

Steindachner, F. 1900. Fische aus dem Stillen Ocean. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1896-97). Denkschr. Math.-Nat. K. K.Wiss. Akad. Wien, 70: 316-318, 483-521 [Author's name misspellt as Steindacher in Ely and Clapp 1973.] [POBSP 1613]

St. John, H. 1970. The genus *Sicyos* (Cucurbitaceae) on the Hawaiian Leeward

Islands. Hawaiian Plant Studies 35. Pacific Sci. 24(4): 439-456. [Pp. 440-443 describes *Sicyos laysanensis* sp. nov. from type taken May 1911 by W. A. Bryan.; pp. 453-456, *S. semitonsus*, sp. nov. from Laysan specimens taken 19 September 1964 by C. R. Long. *Sicyos atollensis*, also newly described, also reported as occurring on Laysan. Other species are described or reported from Nihoa, Kure, Pearl and Hermes, and Lisiansky.]

St. John, H. 1975. *Cenchrus laysanensis* (Gramineae) of the Leeward Islands. Hawaiian Plant Studies 47. Phytologia 31(1): 22-24. [Described from Laysan.]

Stoddart, D. R., and T. P. Scoffin. 1983. Phosphate rock on coral islands. Pp. 369-399 in A. S. Goudie and K. Pye (eds.). Chemical sediments and geomorphology: precipitates and residue in the near-surface environment. Academic Press, London. [Laysan guano, phosphate purity, etc.]

Stoneburner, D. L., and C. S. Harrison. 1981. Heavy metal residues in Laysan Duck feathers. Mar. Pollut. Bull. 12(10): 354-355. [From primaries collected from 10 adults 15 May 1979. Birds had very low levels.]

Stoops, L. 1958. Life on Laysan. Paradise of the Pacific 70(9): 14-15.

Strasberg, D. W. 1956. Notes on the blennoid fishes of Hawaii with descriptions of two new species. Pacific Sci. 10: 241-267.

Studer, T. 1901. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1897-1897). Madreporarier von Samoa, den Sandwich-Inseln und Laysan. Zool. Jahrb., Syst. 14: 388-428. [Reports 18 species, 9 newly described, from specimens collected by Schauinsland.] [POBSP 1591]

Suman, T. W. 1964. Spiders of the Hawaiian Islands: Catalog and bibliography. Pacific Insects 6(4): 665-687. [Lists records for Kure (7 species), Midway (13), French Frigate Shoals (1) and Laysan (9); all records for Laysan appeared in earlier literature with most of those reported by Simon (1898, 1899) being listed with more recent names.] [POBSP 1612]

Svihla, A. 1959. Notes on the Hawaiian monk seal. J. Mammal. 40(2): 226-229. [POBSP 273]

Swezey, O. H. 1914. Two new species of moths from Laysan Island. Proc. Haw. Entomol. Soc. 3(1): 18-19. [*Nesamiptis laysanensis* and *Omiodes laysanensis* from specimens collected in December 1912 by Fullaway] [POBSP 482]

Swezey, O. H. 1926. Lepidoptera. Pp. 73-79 *in* E. H. Bryan et al. 1926. [Lists 6 species, some not specifically identified from specimens taken in April 1923; separately lists specimens reported earlier.]

Tarr, C. L., and R. C. Fleischer. 1995. Evolutionary relationships of the Hawaiian Honeycreepers (Aves, Drepanidinae). Pp. 147-159 *in* W. L. Wagner and V. A. Funk (eds.). Hawaiian Biogeography. Smithsonian Inst. Press, Washington, DC. [Drepanids of Laysan discussed]

Taylor, W. R. 1966. Records of Asian and Western Pacific marine algae, particularly algae from Indonesia and the Philippines. [Records presence in the University of Michigan collections of *Caulerpa mexicana* (Sond.) J. Ag., *C. racemosa* (Forssk.) J. Ag., *C. racemosa* var. *laetevirens* (Mont.) Weber-van-Bosse from Laysan from the 1923 Tanager Expedition.]

Tenorio, J. M. 1976. Catalog of entomological types in the Bernice P. Bishop Museum. Subclass Acari. Pacific Insects 17(1): 7-46. [Lists from Laysan the holotypes of *Ixodes laysanensis* Wilson (p. 21), *Ceratozetes incurvus* Aoki (p. 35), *C. laysanensis* Aoki (p. 36), *Epilohmannia pallida pacifica* Aoki, *Nesoribatula pacifica* Aoki (p. 38), *Scapheremaeus sinuousus* Aoki (p. 40) and *Multioppia wilsoni* Aoki]

Tenorio, J. M. 1979. Catalog of entomological types in the Bishop Museum. Mallophaga. Pacific Insects 20(1): 5-17. [Lists from Laysan the holotype of *Longimenopon puffinus* Thompson (p. 10) and *Halipeurus theresae* Timmerman (p. 13)]

Tenorio, J. M., H. A. Denmark, and S. F. Swift. 1985. Catalog of Acari in the Hawaiian Islands. I. Mesostigmata (or Gamasida) (Acari). Internatl. J. Entomol. 27(4): 297-309. [Lists two species from Laysan but neither represents a new record]

Thomas, C. (ms.). Report of explorations made by the United States Fisheries Commission steamer Albatross in and about the Hawaiian Islands during 1902. Rec. Group 22, U.S. Nat. Arch. 136 pp. [POBSP 1758]

Thompson, G. B. 1948. Mallophaga collected by the Tanager Expedition. B.P. Bishop Mus. Occ. Papers 19: 195-200. [Reports 10 species from specimens collected on Laysan by the Tanager Expedition.] [Among other the Menopodid *Longimenopon puffinus* is described from Laysan?] [POBSP 291]

Thompson, M. C. 1973. Migratory patterns of Ruddy Turnstones in the central Pacific region. Living Bird 12: 5-23. [Table 3, p. 16, lists three recoveries of *Arenaria interpres* banded in the Pribilofs and taken on Laysan 3-17 August 1967.]

Thornton, I. W. B. 1981. The Psocoptera of the Hawaiian Islands. Parts I and II. Introduction and the Nonendmic Fauna. Pacific Instects 23(1-2): 1-49. [Lists species occurrence on the Northwestern Hawaiian Islands including Laysan (3 species), Lisianski (1), Kure (2), Midway (l) and Nihoa (1). Specimens from Laysan included *Cyptophania hirsuta* Banks collected from Wedge-tailed Shearwater and Laysan Albatross nests 9 October 1963, *Lepidolepis pictus* sp. nov., recorded from a bird nest under Eragrostis 15 Jun 1962, and *Ectopsocus fullawayi* Enderlein on the basis of

Zimmerman's 1948 listing.]

Throp, J. 1970. The Laysan Finchbill in the Honolulu Zoo. 'Elepaio 31(4): 31-34. [Discusses behavior, diet, and breeding in captivity of wild-caught Laysan Finches]

Thrum, T. G. 1901. History of the house of H. Hackfield & Co. Hawaiian Almanac and Annual for 1902. pp. 43-54. [The only mention of Laysan occurs on p. 51 which in its entirety reads "This period [1890's] dates another emerging sphere of commercial enterprise, when, with G. N. Wilcox and others, the prosecution was inaugurated of the guano business of Laysan Island, and the establishment therewith of the Pacific Guano and Fertilizer Company, with extensive works at Kalihi under the management of Dr. W. Averdam."

Thrum, T. G. 1905. Hawaiian Almanac and Annual for 1906. T.G. Thrum, Honolulu. 255 pp. [P. 189 notes the wreck of the schooner C. Kennedy, Schlemmer master, a wrecked on Laysan 3 March, her crew rescued by the U. S. Gunboat Petrel on 23 March] [POBSP 1541]

Thrum, T. G. 1923. Northwest Pacific exploration. Pp. 91-94 *in* T. G. Thrum In: Hawaiian Almanac and Annual for 1924 (compiled by T. G. Thrum): 91-94. [Mentions personnel and itinerary of the four cruises of the Tanager Expedition, and remarks on the hordes of rabbits found on Laysan]

Thrum, T. G. 1941. Leeward islands and Palmyra. Thrum's Hawaiian Annual 1940-1941: 45-54. [Brief geography and history of Laysan given on pp. 49-50]

Thurston, L. A., 1923. Notes on the scientific exploring expedition of 1923 to the uninhabited northwestern islands of the Hawaiian group. Honolulu Advertiser, June 1, 1923, pp. 1, 4.

Timberlake, P. H. 1919. Descriptions of new genera and species of Hawaiian Encyrtidae (Hymenoptera). Proc. Haw. Entomol. Soc. 4(1): 197-231. [Describes *Xanthoencyrtus laysanensis* sp. nov. from Laysan from six specimens collected by Fullaway in December 1912]

Timberlake, P. H. 1926. Hymenoptera. Pp. 17-43 *in* in E. H. Bryan et al. 1926. [Lists 3 species from Laysan, all from Fullaway's collections]

Timmermann, G. 1969. Neue Mallophagen aud dem Bernice P. Bishop Museum, Honolulu. Bonn. Zool. Beitr. 20: 244-252. [Describes (p. 249-25-) new mallophagan, *Halipeurus theresae* from a specimen collected from a Bonin Petrel on Laysan, 7 December 1963.]

Tinker, S. W. 1936. Animals of Hawaii. Tongg Publ. Co., Honolulu, HI. Tongg Publ. Co. 190 pp. [Simple book, perhaps for children. Laysan mentioned in context

of remarks on seals; unimportant]

Titgen, R. H., 1987. Hawaiian Xanthidae (Decapoda: Brachyura). I. Specimens at the California Academy of Sciences. B. P. Bishop Mus. Occ. Pap. 27: 106-114. [Includes one record from Laysan from the 1902 Albatross Expedition that apparently has not been previously reported.]

Todd, W. (ms). Extracts from a report of a visit to the Northwestern Hawaiian Islands in September 1918. 4 pp. Bureau of Sport Fisheries and Wildlife, Kailua. [Notes on animals observed on Bird Island (Nihoa), 2 September, Necker (3 September), French Frigate Shoals (5 September), Laysan (8 September), and on Kure Atoll (15 September). Only a few species of birds are mentioned for islands other than Laysan.]

Tomich, P. Q. 1969. Mammals in Hawaii: A Synopsis and Notational Bibliography. Bishop Mus. Spec. Pub. 57. Bishop Museum Press, Honolulu Hawaii. 238 pp. [Mentions seals, rabbits, donkeys, etc. at Laysan in species accounts and has a short chapter on the Northwestern Hawaiian Islands.] [POBSP 1578]

Tomich, P. Q. 1986. Mammals in Hawaii: a synopsis and notational bibliography. Bishop Mus. Spec. Publ. 76: 375 pp. [New edition of Tomich 1969]

Treadwell, A. L. 1906. Polychaetous annelids of the Hawaiian Islands collected by the steamer Albatross in 1902. U.S. Fish. Comm. Bull. 23 (pt. 3): 1145-1181. [Five species reported from Laysan]

Treadwell, A. L. 1925. Polychaetous annelids. Pp. 113-119 in Edmondson et al. 1925.] [Reports 5 species of polychaetes collected at Laysan by the Tanager Expedition, describing one as a new species (*Typosyllis crassi-cirrata*] Check this - relisting of earlier records?.

Trempe, A. D. 1936 ms. [Report on the bird life observed on the cruise of the *Reliance* in March 1936.] Rec. Group 26, U.S. Nat. Arch. 5 pp. [Sketchy notes on birds seen on Nihoa (3rd of March), Necker (4th), French Frigate Shoals (5th), Laysan (7th and 8th), with a few notes on turtles and seals] [POBSP 1547]

Tsuda, R. T. 1965. Marine algae from Laysan Island with additional notes on the vascular flora. Atoll Res. Bull. 110: 31 pp. [Summarizes earlier records and reports algal collections made in April 1923 (43 species or varieties), September 1961 (20), and December 1963 (57). A total of 106 species or varieties listed of which 72 are new records. Also gives observations of 22 species of vascular plants collected in December 1963] [POBSP 1627]

Tsuda, R. T. 1966. Marine benthic algae from the Leeward Hawaiian group. Atoll Res. Bull. 115: 13 pp. [Corrects specific epithets of algae (3 species of *Liagora*

(Rhodophyta), 1 *Halimeda* (Chlorophyta) that were listed inaccurately in Tsuda 1965] [POBSP 1813]

Uchida, R. N., and D. T. Tagami. 1980. Biology, distribution, population structure, and pre-exploitation abundance of Spiny Lobster, *Panulirus marginatus* (Quoy and Gaimard 1825), in the Northwestern Hawaiian Islands. Pp. 157-198 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-01. Vol. 1. [Observations 1976-1981 at Kure, Midway, Pearl and Hermes, Lisianski, Laysan, French Frigate Shoals, Gardner Pinnacles, Necker, Nihoa and various banks. The species was fairly common at Laysan but it was thought that the lobster was present in commercial concentrations only from Maro Reef southeastward.]

Uchida, R. N. and J. N. Uchiyama. (eds.). 1986. Fishery atlas of the Northwestern Hawaiian Islands. NOAA Tech. Rep. 38. 142 pp. [Includes Laysan]

Uchida, R. N. J. H. Uchiyama, R. L. Humphreys, Jr., and D. T. Tagami. 1980. Biology. distribution and estimates of apparent abundance of the Spiny Lobster, *Panulirus marginatus* (Quoy and Gaimard), in waters of the Northwestern Hawaiian Islands. Part 1. Distribution in relation to depth and geographical areas and estimates of apparent abundance. Pp. 121-130 *in* R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands. Seagrant Misc. Rep., UNIHI-SEAGRANT - MR-80-04. [Observations at Kure, Midway, Pearl and Hermes, Lisianski, Laysan, French Frigate Shoals, Gardner Pinnacles, Necker, Nihoa and various banks.]

Uchiyama, J. H. 1980. Survey of pelagic fishes of the Northwestern Hawaiian Islands. Pp. 251-263 in R. W. Grigg and R. T. Pfund (eds.). Proc. Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands. Seagrant Misc. Rep. UNIHI-Seagrant-MR-90-04. [Tabulated data and map of coastal pelagic fishes around Laysan.]

Uchiyama, J. H., S. H. Kuba, and D. T. Tagami. 1984. Length-weight and standard length-fork length relationships of deepsea handline fishes of the Northwestern Hawaiian Islands. Pp. 209-225 *in* R. W. Grigg and K. Y. Tanoue (eds.). Proc. Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands. Vol. 2. Seagrant Misc. Rep. UNIHI-84-01. [Data from RV Townsend Cromwell cruises from August 1978 to September 1981 for all the Northwestern Hawaiian Islands and a variety of banks and reefs for seven species of fish: *Seriola dumerili*, *Pseudocaranx dentax*, *Pristipomoides filamentosus*, *P. sieboldii*, *P. zonatus*, *Etelis carbunculus*, and *Epinephelus guernus*.]

Uchiyama, J. H., and D. T. Tagami. 1984. Life history, distribution , and abundance of bottomfishes in the Northwestern Hawaiian Islands. Pp. 229-247 *in* R. W. Grigg and K. Y. Tanoue (eds.). Proc. Second Symposium on Resource

Investigations in the Northwestern Hawaiian Islands. Vol.1. Seagrant Misc. Rep. UNIHI-84-01. [Data from RV Townsend Cromwell cruises from October 1976 to August 1981 for all the Northwestern Hawaiian Islands and a variety of banks and reefs for eight species of fish: *Epinephalus quernus*, *Pseudocaranx dentax*, *Seriola dumerili*, *Pristipomoides filamentosus*, *P. sieboldii*, *P. zonatus*, *Etelis carbunculus*, and *E. coruscans*.]

Udvardy, M. D. F. 1961a. Additions to the check list of Hawaiian birds. 'Elepaio 21(12): 83-90. [Lists records for three species from Laysan that are additional to those listed by Bryan 1958] [POBSP 890]

Udvardy, M. D. F. 1961b. The Harold J. Coolidge Expedition to Laysan Island, 1961. 'Elepaio 22(6): 43-47. [POBSP 900]

Udvardy, M. D. F. 1963. Data on the body temperatures of tropical sea and water birds. Auk 80: 191-194. [Data from visits in July 1959 and September 1961 on Black-footed and Laysan albatross, Wedge-tailed and Christmas shearwaters, Bonin Island and Bulwer's petrels, Masked Booby and Laysan Duck] [POBSP 966]

Udvardy, M. D. F. 1972. Laysan Albatross as carrier of floating debris to land. Atoll. Res. Bull. 162: 9. [Some, but not all of the pumice and plastic found at the highwater line of Laysan lagoon is brought in by the albatross. The rest is brought in by winter storms that break over the outer beaches.]

Udvardy, M. D. F. 1995. Three months on a coral island [Laysan] by Hugo H. Schauinsland. Translation by Miklos D. F. Udvardy. [See Atoll Research Bulletin 432 in this volume.]

U. S. Fish and Wildlife Service. 1969. Hawaiian Islands National Wildlife Refuge. Refuge Leaflet 508.

U. S. Fish and Wildlife Service. 1971. Birds of the Hawaiian Islands National Wildlife Refuge. Refuge Leaflet 211 R-1

U. S. Fish and Wildlife Service. 1973. Threatened Wildlife of the United States. U. S. Bureau Sport Fish. Wildl. Res. Publ. 114. [Laysan Duck]

U. S. Fish and Wildlife Service. 1982. Laysan Duck recovery plan. U. S. Fish and Wildlife Service, Portland, Oregon. 38 pp. [Miscellaneous information including populations estimates by USFWS through July 1980.

U. S. Fish and Wildlife Service. 1983ms. Seabird Atlas of Hawaii. Typescript, U.S. Fish and Wildlife Service, Honolulu, Hawaii.

U. S. Fish and Wildlife Service. 1984. Northwestern Hawaiian Islands Passerines

Recovery Plan. U. S. Fish and Wildlife Service, Portland, Oregon. [Not seen]

U. S. Fish and Wildlife Service. 1986. Hawaiian Islands National Wildlife Refuge Final Master Plan/Environmental Impact Statement (FES#86/11). U. S. Dept. Interior, U. S. Fish and Wildlife Service, Region One, Portland, Oregon. [All islands mentioned. Of particular interest are Tables 1 and 2 (p. 3-13 and pp. 3-14 to 3-15) which list candidate endangered plant and invertebrate species occurring on Laysan and the other islands. Six plants, 2 beetles and 5 moths are listed for Laysan.]

van Riper, S. G., and C. van Riper III. 1982. A Field Guide to the Mammals in Hawaii. The Oriental Publishing Company, Honolulu, Hawaii. 68 pp. [Laysan rabbit situation discussed]

van Riper, S. G., and C. van Riper III. 1985. A summary of known parasites and diseases recorded from the avifauna of the Hawaiian Islands. Pp. 298-371 *in* C. P. Stone and J. M. Scott (eds.). 1985. Hawai'i's terrestrial ecosystems: Preservation and Management. Honolulu, Univ. Hawaii Press. 584 pp. [Includes previous records on the birds of Laysan.]

Vaughan, T. W. 1907. Recent Madreporia of the Hawaiian Islands and Laysan. U.S. Nat. Mus. Bull. 59: ix and 222 pp. [Reports corals collected by Albatross Expedition; revises some of Studer's taxonomy, and describes several new species including *Balanophyllia laysanensis*.] [POBSP 8]

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1990. Manual of the flowering plants of Hawaii. Univ. of Hawaii Press, Honolulu, Hawaii. 2 vols. University of Hawaii Press and Bishop Museum Press, Honolulu. 1853 pp. [Provides detailed descriptions and black-&-white drawings of all Laysan plants]

Wagner, W. L., D. R. Herbst, and S. H. Sohner. 1989. Contributions to the Flora of Hawai'i. II. Begoniaceae -- Violaceaa and the monocotyledons. B. P. Bishop Occ. Pap. vol. 29: 88-130. [P. 124 gives 1980 observations of *Mariscus pennatiformis* subsp. *bryanii* on Laysan.]

Walker, F. D. 1909. Log of the Kaalokai. The Hawaiian Gazette Co., Ltd., Honolulu. 64 pp.

Walker. R. L. 1961ms. Excerpts from Leeward Island journal, September 2nd to 12th, 1961. Hawaii Dept. of Fish and Game, Honolulu, HI. 4 pp.

Walker, R. L. 1963ms. Notes on a visit to Laysan Island, December 3-10, 1963. Hawaii Dept. of Fish and Game, Honolulu, HI. 25 pp.

Walker, R. L. 1964ms a. A report on a survey trip to Laysan Island, November 30-December 12, 1963. 10 pp., and plates and figures. Hawaii Div. Fish and Game,

Honolulu, HI. [Not seen; from Hiruki and Ragen 1992]

Walker, R. L. 1964ms b. Leeward Hawaiian Islands expedition, field notes, March 5-22, 1964. 35 pp. Hawaii Div. Fish and Game, Honolulu, HI. [Not seen; from Hiruki and Ragen 1992]

Walker, R. L. 1964ms c. Report on a March, 1964 visit to Nihoa, Laysan, Lisanski, Pearl and Hermes Reef. Hawaii Div. Fish and Game; Honolulu, HI

Walker, R. L. 1966ms. Photo station record, Hawaiian Islands Wildlife Refuge (French Frigate Shoals, Laysan, Pearl and Hermes Reef) - March 17 to April 5, 1966.) [Photographs available from Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife, Honolulu, HI.]

Walker, R. L. 1967ms. Photo station record, Hawaiian Islands Wildlife Refuge, Nihoa, Laysan, Lisianski, Pearl and Hermes Reef, September 11-30, 1967. [Photographs available from Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife, Honolulu, HI.

Warner, R. E. ms. Completion report. Midway and Laysan Islands bird studies. Hawaii Dept. of Fish and Game, Honolulu, HI. 11 pp. [POBSP 1036]

Warner, R. E. 1958. Wildlife of Laysan Island. 'Elepaio 19(2,4): 8-10, 20-23. [Observations made during visit in May-June 1958] [POBSP 845]

Warner, R. E. 1959. Present status of the avifauna of the Hawaiian Islands - an appraisal. 'Elepaio 20(3): 16-19. [A few remarks are given on p. 18 on the effects on Laysan of commercial guano mining in the late 1800s.] [POBSP 866]

Warner, R. E. 1963. Recent history and ecology of the Laysan Duck. Condor 65(1): 3-23. [From historical information and from observations on periodic visits from 1957-1959 and in 1961. Gives information on habitat, home range, populations, mortality, food habits, sexual dimorphism, breeding habits and behavior] [POBSP 934]

Warner, R. E. 1968. The role of introduced diseases in the extinction of the endemic Hawaiian avifauna. Condor 70(2): 101-120. [Pp. 107-111 treat birdpox and avian malaria induced in Laysan Finches that were exposed to the environment in Oahu and Kauai, showing that they had no natural resistance to these diseases. The studies were conducted with 24 and 36 finches removed from Laysan in June 1958 and July 1959, respectively.]

Watson, J. S. 1961. Feral rabbit populations on Pacific Islands. Pacific Sci. 15(4): 591-593. [Describes in detail the fate of rabbits on Laysan Island.] [POBSP 256]

Watson, R. T., and G. A. Peiterson. 1984. Scat and spew analysis of the Hawaiian

Monk Seal, *Monachus schauinslandi*. P. 343 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-01. Vol. 2. [Abstract only; based in part on samples from Laysan]

Weathers. W., and C. van Riper III. 1982. Temperature regulation in two endangered Hawaiian honeycreepers: the Palila (*Psittirostra bailleui*) and the Laysan Finch (*Psittirostra cantans*). Auk 99(4): 667-674. [Based on studies of captive Laysan Finches at Hawaii Field Research Center]

Weller, M. W. 1980. The island waterfowl. Iowa State Univ. Press, Ames.

Werner, F. 1901. Ergebnisse einer Reise nach dem Pacific (Schauinsland 1896-97, Reptilien. Zool. Jahrb., Syst. 14: 380-387. [Reports two species collected on Laysan: *Hemidactylus garnoti* DB (p. 382) and *Ablepharus boutoni* Desj., var. *poecilopleura* Wiegm.] [POBSP 1591]

Westlake, R. L., and W. G. Gilmartin. 1990. Hawaiian Monk Seal pupping locations in the Northwestern Hawaiian Islands. Pacific Sci. 44(4): 366-383. [Records for Nihoa, Necker. French Frigate Shoals. Laysan, Lisianski, Pearl and Hermes Reef, Midway and Kure]

Wetmore, A. 1923ms. Field notes taken on the 1923 Tanager Expedition (original in the archives of the Smithsonian Institution). [Published in this volume as part of Atoll Research Bulletin 433]

Wetmore, A. 1925. Bird life among lava rock and coral sand. Nat. Geogr. Mag. 48: 77-108. [POBSP 555]

Wetmore, A. 1938. A note on *Fregata*. Raffles Mus. Singapore Bull. 14: 47. [Shows photograph of (dead) Great Frigatebird taken on Laysan 2 May 1923.] [POBSP 1360]

Wheeler, W. M. 1934. Revised list of Hawaiian ants. B.P. Bishop Mus. Occ. Papers 10 (21): 1-21. [Lists 8 species from Laysan based on collections by Fullaway and Schauinsland; also lists collections at quarantine stations of Honolulu from ships coming from various places in Asia, Europe, etc.] [POBSP 447]

Whittow, G. C. 1993a. Black-footed Albatross (*Diomedea nigripes*). (A. Poole and F. Gill, eds.) The Birds of North America No. 65: 16 pp. [Account summarizing distribution and natural history makes one mention of Laysan: its breeding population, 14000-21000 pairs, is the largest known for the species.]

Whittow, G. C. 1993b. Laysan Albatross (*Diomedea immutabilis*). (A. Poole and F. Gill, eds.) The Birds of North America No. 66: 20 pp. [Account summarizing

distribution and natural history makes secondary mention of Laysan several times, with regard to killing by man, devegetation of the island by rabbits, and to expanding populations.]

Whittow, G. C., G. S. Grant, and E. N. Flint. 1985. Egg water loss, shell water vapour, and the incubation period of the Gray-backed Tern (*Sterna lunata*). Condor 87(2): 269-272. [Based on eggs from Eastern Island, Midway Atoll, and Laysan Island.]

Wilder, G. P. 1905. A short trip to the Midway Islands with Capt. A.P. Niblack in the U.S.S. "Iroquois." Hawaiian For. and Agr. 2: 390-396.

Wilder, G. P. (ms. a). Extracts from a letter received by the Bureau of Biology Survey on 12 May 1924. 1 p. Bureau of Sport Fisheries and Wildlife, Kailua. [Sketchy notes on 5 species of birds; no rabbits were seen during visit.] [POBSP 1560]

Wilder, G. P. 1930 ms. Report of a trip to Laysan in the summer of 1930. Rec. Group 22, U.S. Natl. Archives. 4 pp. [Visit 2-16 August during which Wilder planted 60 trees of various species "as well as seeds of grass, vines, and some beans." as well as collecting a variety of plants already present. Mentions that Wilder took several pairs of the Laysan Rail to Midway in 1904 and that but a single Laysan Duck with nest with eggs was found.] [POBSP 1550]

Willett, G. 1919. Notes on the nesting of two little-known species of petrel. Condor 21: 60-61. [Observations of Bonin Petrel on Laysan and Sooty Storm Petrel on Laysan and Pearl and Hermes Reef] [POBSP 959]

Willett, G. (ms.). [Extracts from a report made to the Bureau of Biological Survey], Bureau of Sport Fisheries and Wildlife, Kailua, Hawaii. [Notes on birds at Necker, Nihoa, French Frigate Shoals, Laysan (4 pp.), Lisianski, and Pearl and Hermes Reef during survey in 1912-1913. For Laysan an annotated list of birds is given with some detail on accidental species collected. It also gives brief notes on the occurrence of the Fox Gecko (*Hemidactylus garnotii*) and Snake-eyed Skink (*Ablepharus boutonii*).][POBSP 1560]

Wilson, C. B. 1950. Copepods gathered by the United States Fisheries Steamer Albatross from 1887 to 1909... U.S. Nat. Mus. Bull. 14 (3): 141-441. [Reports a copepod collected north of Laysan by the Albatross Expedition] [POBSP 1570]

Wilson, N. 1964. *Ixodes laysanensis*, a new species of tick from birds on Laysan Island (Metastigmata: Ixodidae). J. Med. Entomol. 1(2): 165-168. [From specimen collected in December 1963] [POBSP 1022]

Wilson, S. B. 1890. On a new finch from Midway Island, north Pacific. Ibis 7: 339-341. [*Telespyza cantans*, sp nov.; the Laysan Finch described from birds

introduced to Midway] [POBSP 992]

Wilson, S. B., and A. H. Evans. 1890-1899. Aves Hawaiienses. London, R. H. Porter. 257 pp. [Mention of Laysan is made in a number of species accounts, but the material is entirely derivative, being based on Palmer's observations in 1891 which were reported fully by Rothschild.]

Wirtz, W. O., II. 1965ms. Leewards Islands Survey...March 1965. POBSP unpublished ms., Smithsonian Institution, Washington, DC. 26 pp. [SIA 37, 163, 13]

Wirtz, W. O., II. 1968ms. Population dynamics and interatoll movements of the Hawaiian monk seal. Pacific Ocean Biol. Survey Program. Smithsonian Inst. Washington, D.C. 24 pp.

Withers, N. W. 1984. Ciguatera research in the Northwestern Hawaiian Islands: laboratory and field studies on ciguatoxigenic dinoflagellates in the Hawaiian archipelago. Pp. 144-156 *in* R. W. Grigg and K. Y. Tanoue. (eds.). Proc. Second Symp. Resource Invest. in the Northwestern Hawaiian Islands. Univ. Hawaii Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-84-0l. Vol. 1. [Table 1 reports results of surveys for *Gambierdiscus toxicus*, a dinoflagellate precursor of ciguatera, including those in November 1980 at Nihoa, French Frigate Shoals and Laysan and August 1981 at French Frigate Shoals. Species was present in all 11 samples taken on the west and southwest reefs of Laysan 16 November but not found in two samples on wave lapped rock ledge the following day.]

Woodside, D. H. 1957ms. a. Report on the population of Laysan Teal and the transport of teal to [the] Honolulu Zoo. [1957]. Hawaii Dept. of Fish and Game, Honolulu. 4 pp., typescript. [Observations made on Laysan 25 June-3 July 1957 include notes on broods and nests and a map showing the route taken during the census, from which an estimate of 740 adults was derived.] [POBSP 166]

Woodside, D. H. (ms. b). Notes on a survey of Laysan Island, July 1957. Hawaii Dept. of Fish and Game, Honolulu.

Woodside, D. H. 1961ms. Report on a survey of Laysan Island, September 1961. Hawaii Dept. of Fish and Game, Honolulu. i and 32 pp. [POBSP 160]

Woodside, D. H. and R. J. Kramer. 1961ms. A report on a survey trip to the Hawaiian Islands' National Wildlife Refuge, March 1961. Hawaii Dept. of Fish and Game, Honolulu. 32 pp. [POBSP 155]

Woodward, P. W. and R. B. Clapp. 1969. First records of Baird's Sandpiper from the central Pacific. 'Elepaio 30(3): 25. [Reports specimens (USNM 543044, 543045) of *Calidris bairdii* collected on Laysan 6 Sept 1987 and on Oahu (USNM 544275) 23 August 1968]

Yamashita, S. 1968. 'Forgotten Hawaii' The Leeward Islands. Sunday Star-Bulletin and Advertiser, Honolulu. P. A-8. [Unimportant comments of Laysan with picture showing Eugene Kridler among Sooty Tern colony there]

Yates, L. G. 1897. The Layson Islands. [Sic] Overland Monthly 30: 453-455. [Brief description with notes on birds and guano.] [POBSP 430]

Yuen, H. S. H. 1976ms. Cruise Report, R/V Townsend Cromwell, cruise 76-04-71, May 3-June 9, 1976. Northwestern Hawaiian Islands and waters off Oahu. U. S. Dep. Comm., NOAA, NMFS, Southwest Fish. Center, Honolulu and La Jolla Laboratories. 8 pp. [Not seen; from Hiruki and Ragen 1992]

Zimmerman, E. C. 1948a. Insects of Hawaii. Vol. 2. Apterygota to Thysanoptera. Univ. of Hawaii Press, Honolulu. vii and 475 pp. [Lists 3 cockroaches, an embiopterid, an earwig and 10 mallophaga from Laysan.] [POBSP 470]

Zimmerman, E. C. 1948b. Insects of Hawaii. Vol. 3. Heteroptera. Univ. of Hawaii Press, Honolulu. v and 255 pp. [Lists a nabid and a mirid from Laysan.] [POBSP 470]

Zimmerman, E. C. 1948c. Insects of Hawaii. Vol. 4. Homoptera: Anchenorhyncha. Univ. of Hawaii Press, Honolulu. vii and 268 pp. [Lists a delphacid from Laysan] [POBSP 470]

Zimmerman, E. C. 1948d. Insects of Hawaii. Vol. 5. Homoptera: Sternorhyncha. Univ. of Hawaii Press, Honolulu. vii and 464 pp. [Lists a coccid from Laysan] [POBSP 470]

Zimmerman, E. C. 1957. Insects of Hawaii. Vol. 6. Ephemeroptera-Neuroptera-Trichoptera and supplement to Vols. 1 to 5. Univ. of Hawaii Press, Honolulu. ix and 209 pp. [Supplement lists an embiopterid from Laysan] [POBSP 1688]

Zimmerman, E. C. 1958a. Insects of Hawaii. Vol. 7. Macrolepidoptera. Univ. of Hawaii Press, Honolulu. ix and 542 pp. [Lists 6 noctuid moths from Laysan] [POBSP 1603]

Zimmerman, E. C. 1958b. Insects of Hawaii. Vol. 8. Lepidoptera: Pyraloidea. Univ. of Hawaii Press, Honolulu. ix and 456 pp. [Lists 3 pyralids and a pterophorid from Laysan.] [POBSP 1614]

ATOLL RESEARCH BULLETIN

NOS. 432–434

NO. 432. THREE MONTHS ON A CORAL ISLAND (LAYSAN)
BY HUGO H. SCHAUINSLAND [1899]
TRANSLATED BY MIKLOS D.F. UDVARDY

NO. 433. HISTORY AND ORNITHOLOGICAL JOURNALS OF THE *TANAGER* EXPEDITION OF 1923 TO THE NORTHWESTERN HAWAIIAN ISLANDS, JOHNSTON AND WAKE ISLANDS
BY STORRS L. OLSON

NO. 434. AN ANNOTATED BIBLIOGRAPHY OF LAYSAN ISLAND, NORTHWESTERN HAWAIIAN ISLANDS
BY ROGER B. CLAPP, MIKLOS D.F. UDVARDY AND ANGELA KAY KEPLER

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